The evolution of lean Six Sigma

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Abstract

Purpose – Although research has been undertaken on the implementation of lean within various industries, the many tools and techniques that form the "tool box", and its integration with Six Sigma (mainly through case studies and action research), there has been little written on the journey towards the integration of the two approaches. This paper aims to examine the integration of lean principles with Six Sigma methodology as a coherent approach to continuous improvement, and provides a conceptual model for their successful integration.

Design/methodology/approach – Desk research and a literature review of each separate approach is provided, followed by a view of the literature of the integrated approach.

Findings – No standard framework for lean Six Sigma or its implementation exists. A systematic approach needs to be adopted, which optimises systems as a whole, focusing the right strategies in the correct places.

Originality/value – This paper contributes to knowledge by providing an insight into the evolution of the lean Six Sigma paradigm. It is suggested that a clear integration of the two approaches must be achieved, with sufficient scientific underpinning.

Keywords Lean production, Six sigma

Paper type Literature review

1. Introduction

The Toyota Production System (TPS) provided the basis for what is now known as lean thinking, as popularised by Womack and Jones (1996). The development of this approach to manufacturing began shortly after the Second World War, pioneered by Taiichi Ohno and associates, while employed by the Toyota motor company. Forced by shortages in both capital and resources, Eiji Toyoda instructed his workers to eliminate all waste. Waste was defined as "anything other than the minimum amount of equipment, materials, parts, space and time which are absolutely essential to add value to the product" (Russell and Taylor, 2000, p. 737).

Working to this brief through a process of trial and error, Ohno would go on to achieve a new manufacturing paradigm – the Toyota Production System (TPS) (White and Prybutok, 2001). The TPS became the dominant production model to emerge from a number of concepts around at the time (Katayama and Bennett, 1996; Bartezzaghi, 1999). As a result of the International Motor Vehicle Program (IMVP) benchmarking study, and the work of Womack *et al.* (1990), US and European companies began adapting the TPS under the title of just-in-time (JIT) to remain competitive with Japanese industry.

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2. The lean philosophy

Lean manufacturing extends the scope of the Toyota production philosophy by providing an enterprise-wide term that draws together the five elements of "the product development process, the supplier management process, the customer management process, and the policy focusing process for the whole enterprise" (Holweg, 2007, p. 430). The foundation of the lean vision is still a focus on the individual product and its value stream (identifying value-added and non-value added activities), and to eliminate all waste, or *muda*, in all areas and functions within the system – the main target of lean thinking (Womack and Jones, 1996). Seven forms of waste have been identified:

(1) over-production;

(2) defects;

(3) unnecessary inventory;

(4) inappropriate processing;

(5) excessive transportation;

(6) waiting; and

(7) unnecessary motion.

The first step in a lean transition is to identify value-added and non-value adding processes. Value stream mapping (VSM) emerged for this role (Rother and Shook, 1999), and continues to provide a reliable qualitative analysis tool (if implemented correctly). It also provides the scope of the project by defining the current state and desired future state of the system. This future state map is then used to develop lean improvement strategies, for example parallel working and flexibility through multi-skilling employees (requiring minimal expenditure).

The benefits of VSM are many, including the provision of a common language when considering manufacturing processes. It also brings together all of the lean techniques, which helps practitioners avoid the temptation to cherry-pick one or two of the "easier" to implement. In fact, no other tool depicts the linkages between information and material flow like VSM (Rother and Shook, 1999). Their book *Learning to See* has become the definitive text for organisations starting a lean journey.

VSM has its critics. Sheridan (2000) suggested that the practical nature of VSM (i.e. the paper and pencil approach) limits the amount of detail collected and also detracts from the actual system workings (the action of using pencil and paper to draw the map may remove focus from the actual system being analysed). This dynamic view looks beyond VSM as giving a quick, succinct overview of where "*muda*" is present, and develops the idea of the mapping process itself becoming a continuous tool, constantly being updated via software (Sheridan, 2000).

Using software can increase the data that can be represented compared to paper and pencil. Academics such as McDonald *et al.* (2002), Lian and Landeghem (2002) and Abdulmalek and Rajgopal (2007) have explored the integration of VSM with simulation. A multitude of VSM software (e.g. eVSM) is available over the internet. Such software presents the user with a dynamic view of the value stream (not static), allowing observation of the "real-time" impact of proposed improvements. Essentially it increases flexibility and information available to improvement teams. However, it is the relative simplicity of VSM that has made it such a powerful tool for change. More complex analysis such as simulation modelling can take months to complete, by which time momentum can be lost or the system has changed, making the model invalid.

Solely mapping a value stream is commonly misconceived as lean. The lean philosophy must be understood as a holistic one. To achieve a truly lean operation, VSM needs to be methodically applied before other tools such as single minute exchange of die (SMED) and 5S. Perhaps the most widely used of the lean tools is 5S (concerned with a cultural change in the organisation, making systematic and standardised processes normal routine, i.e. good housekeeping and not an exception). 5S is seen as fundamental to achieving a lean business and is deemed equally applicable to the shop floor or office (Bicheno, 2000). Implementing 5S before anything else equally runs the risk of organisations' focus of improvement being consumed with 5S, detracting from the rest of the viable techniques that will lead to sustainable changes within the system. This is not to say that 5S is not a powerful approach, but it is self-limiting unless implemented as part of a whole, well-managed initiative.

This mix of lean tools have provided academics with a rich resource for applied research, with examples including SMED (Mileham *et al.*, 1999), total production maintenance (TPM) (Bamber *et al.*, 1999; Ireland and Dale, 2001), VSM (McDonald *et al.*, 2002; Abdulmalek and Rajgopal, 2007) and 5S (Warwood and Knowles, 2004).

3. Lean success

Originally, lean philosophies were applied to large manufacturing operations in high-volume, low-variety facilities. Not surprisingly, following its inception at Toyota, some of the first Western companies to consider the transition to a lean culture were US automotive manufacturers. The reason for this is two-fold. Firstly, these companies were in direct competition with Toyota, and were watching from a distance as their market share shrank to Toyota's emerging dominance. Secondly, the market was becoming increasingly demanding for greater choice in product portfolios. Japanese-managed plants were continuously outperforming their American counterparts. Between the years of 1968 and 1978, US productivity increased by 23.6 per cent, but the Japanese experienced an impressive 89.1 per cent increase (Teresko, 2005). Their response was to negotiate strategic partnerships between themselves (major US) and Japanese car manufacturers, such as Mazda and Ford (Chan and Wong, 1994), and the New United Motor Manufacturing, Inc. (NUMMI), set up between General Motors and Toyota (Chan and Wong, 1994, Waurzyniak, 2005), enabling the West to take advantage of the TPS paradigm. Additionally, these alliances reduced risk for the Japanese partners (Chan and Wong, 1994), normally associated with the development of overseas facilities.

Unsurprisingly, successful initiatives can be found in the automotive and aerospace sectors. Mitsubishi started a joint venture with Volvo (NedCar) that saw the same advantages experienced through the NUMMI initiative. They used IT to monitor production and provide real-time data, and identified "wasteful" downtime, and an effort was made to reduce this, resulting in increased production efficiency and team morale (*Quality*, 2004). Chrysler used resources to extend in-house training of lean philosophy to its major suppliers, emphasising the commitment needed from all parties in order to establish lean, and realise the full potential for everyone involved (Fitzgerald, 1997).

Delphi took a multi-pronged approach, looking at supplier development, cost management, strategic sourcing and quality issues (among others), led by top management, again emphasising the long term commitment needed, and highlighting the importance of knowledge management to provide clear examples for the automotive sector (Nelson, 2004).

Lynds (2002) recognised the importance of leadership and commitment needed by top management to embrace and roll out the lean approach. Of course, this requires effective company-wide communication and feedback. In this example, production floor space was reduced, creating unused space that could be sold for capital. Such activities are labelled as "common sense" in this article; this can lead to lean being dismissed as an improvement approach as well as to some lean strategies seeming counter-intuitive (e.g. reducing inventory). Excess has traditionally been thought of as a safety net to buffer any system nervousness.

4. Limited success of lean

The automotive industry's adoption of lean does not escape criticism (Parker and Slaughter, 1994; Rinehart *et al.*, 1997). This seems to stem from a lack of understanding, direction and/or commitment from management (Hancock and Zayko, 1998), not helped by the heavily unionised culture of the industry (Hall, 1992). Management and their communications provide the backbone of any continuous improvement effort, while employees require transparency from management and their own education and empowerment in the change process.

In a development beyond lean's initial application to low-variety, high-volume facilities, attention has been given to the viability of applying lean principles to "job-shop" companies, i.e. high-variety, low-volume (Winter, 1983; Jina *et al.*, 1997; Hendry, 1998; Irani, 2001). Research (Boughton and Arokiam, 2000) suggests that lean applications are essential for survival and growth in today's job-shop industry. This has been brought into question through the suggestion that value-added activities do not take into account the size, complexity or manufacturability of a product. Therefore if the theory behind lean is flawed, then the "universality of lean must clearly be questionable" (James-Moore and Gibbons, 1997). As discussed by Irani (2001), job-shops face the toughest obstacle when trying to map and analyse the flow of 100-2,000 + product routes through their facility. Complicated and in-depth algorithms and often prohibitively expensive IT solutions are needed to overcome this difficult scheduling task.

Ultimately, lean implementation has not been as successful here as in their mass producing counterparts for three main reasons. Firstly, huge product portfolios mean that each "job" is likely to be different and therefore production approaches cannot be standardised. Secondly, the products' characteristics create production constraints. Thirdly, the job-shops or smaller firms simply cannot match the dominance or resources that the larger firms enjoy, allowing them to be inflexible along their supply chains (Bamber and Dale, 2000).

The view that lean is pro-company, not pro-employee, has some validity, and cannot be dismissed. For example, it is said that employees feel a sense of insecurity, perceiving lean as a redundancy threat. The opinion is also held that management avoid accountability when problems arise, letting it filter downwards onto the lower levels of hierarchy (Parker and Slaughter, 1994). This is to miss the fundamental underpinning of empowerment and cultural change, resulting from a failure by management to approach lean with the correct goals. Lean requires and relies on a review of organisational values, which in itself is key to sustainability of lean. Without this we see an adverse affect on morale, increasing levels of worker unhappiness and withdrawal, ultimately leading to operational failures (Hines *et al.*, 2004).

Lean should be used as an enabler for strategic development rather than a tool for downsizing. Management tend to concentrate on tools and practices, rather than viewing lean as a philosophy, aiming to teach new improvement tools to employees, rather than immersing them in the practical side of solving opportunities for improvement with a lean approach (Spear, 2004).

5. Six Sigma

Six Sigma as recognised today was developed at Motorola through the efforts of Bill Smith, a reliability engineer, in the 1980s (Brady and Allen, 2006). The real turning point in Six Sigma's popularity came through the work of Jack Welch, the then CEO of General Electric in 1995. Welch had observed the success experienced through Bill Smith's approach and intensely championed and led the Six Sigma methodology in GE (Black and Revere, 2006).

The term "Six Sigma" refers to a statistical measure of defect rate within a system. Underpinned by statistical techniques, it presents a structured and systematic approach to process improvement, aiming for a reduced defect rate of 3.4 defects for every million opportunities, or Six Sigma (Brady and Allen, 2006). To help illustrate the meaning of Six Sigma defect rates within a system, Pande *et al.* (2000) provide some useful examples of the difference between 99 per cent quality and the superior rate of Six Sigma quality in a number of different situations. For example, if the post office was working at a 99 per cent quality rating, for every 300,000 letters delivered there would be 3,000 misdeliveries, compared to only one misdelivery if they were operating at a Six Sigma level. If television stations operated at 99 per cent there would be approximately 1.68 hours of dead air time experienced per week in comparison to the 1.8 seconds experienced if working at Six Sigma levels (Pande *et al.*, 2000).

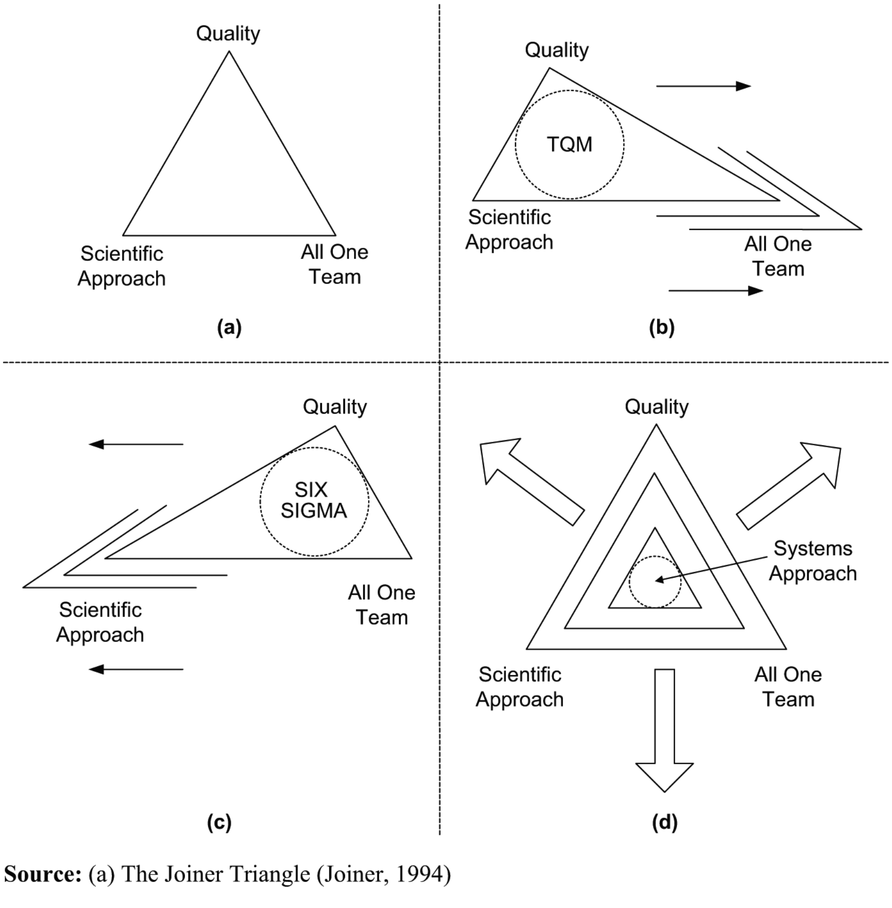
Six Sigma brings structure to process improvement by providing the user with a more detailed outline of Deming's plan-do-check-act cycle by guiding the initiative through a five stage cycle of define-measure-analyse-improve-control (DMAIC) (Pande *et al.*, 2000; Andersson *et al.*, 2006). Each stage has a number of corresponding tools and techniques such as statistical process control, design of experiments and response surface methodology, providing the user with an extensive tool box of techniques, in order to measure, analyse and improve critical processes in order to bring the system under control (Keller, 2005).

Training of key staff is critical in order to follow the DMAIC cycle effectively and gain significant results, as is the buy-in of senior management if the initiative is to take root. Management must play an active role in the selection of projects for the newly trained Six Sigma teams to focus on, and also ensure that all required resources are made available (Raisinghani, 2005). From this, the roles required for implementation must be specifically defined and made clear within the organisation before embarking on the Six Sigma journey, so that everyone involved knows their responsibilities, exactly what needs to be done and in what order (Pande *et al.*, 2000). It is essential that Six Sigma should be understood to be a philosophy as well as a scientific approach and this has growing acceptance (Keller, 2001).

Six Sigma needs to evolve if it is to remain a relevant and sustainable approach for business. McAdam and Lafferty (2004) suggest that it needs to be embraced as a continuous improvement management philosophy in order to embed itself in the psyche of organisations. Six Sigma has "some way to go before it is fully accepted as a broad change philosophy" (McAdam and Lafferty, 2004, p. 546). These authors go on to show that Six Sigma is not in fact a replacement for total quality management (TQM), but refocuses the mechanised side of it, providing important business metrics. This is key when looking at the broader context of Six Sigma, and its roots in the TQM approach.

From this, it is useful to consider the pioneering work of Joiner (1994), and the Joiner Triangle (Figure 1a), to understand the distinct shift in how quality management initiatives have been embraced by business.

The original Joiner Triangle is equilateral in nature, depicting the equally interrelated core elements of "fourth generation management". However, when using the above to reflect upon the evolution of the TQM philosophy, the Joiner Triangle becomes skewed (Figure 1b), as management focus became disproportionately geared towards the organisations people and the philosophical and cultural concepts behind total quality. Quality was still the driving force, but it lost emphasis on the scientific approach. The circle in this diagram represents the conduit that holds together the essence of all three points of the triangle.



Source: (a) The Joiner Triangle (Joiner, 1994)

Figure 1. The shifting focus of quality

At this stage in the evolutionary path, it is the "philosophy" holding all of the parts together. TQM was a loosely based philosophy based on ideas (and therefore not unified) of Deming, Juran, Crosby, Feigenbaum, etc., i.e. "One God, many prophets" (Hand, 1992). This philosophy did not provide or sustain the necessary conduit for the people side of quality to be integrated to a scientific approach, thus leaving it impossible to dynamically maintain.

Moving on from this, the Six Sigma methodology has brought about another change in focus. This has the result of skewing the Joiner Triangle in the opposite direction, so that the scientific approach is emphasised (Figure 1c), at the cost of the critical people element (the binding substance represented by the circle in this case is the structured and focused methodology). Failing to integrate the cultural aspects of continuous improvement is again self-limiting. A solution therefore is to embed a coherent systems philosophy that integrates culture with a scientific approach through a unified hard/soft systems thinking philosophy.

The shift in focus depicted between Figures 1b and c is a direct result of the loose associations between quality, the scientific approach, and the people perspective inherent in any system. These associations must be tightened and equally managed, if we are to achieve a sustainable outlook for continuous improvement. In other words, we need to aim for an equal growth on each side of the triangle, taking a systems view of the organisation as an organic, complex entity (Figure 1d).

Figure 1d better represents the objectives of continuous improvement, returning to the strengths of the original Joiner Triangle – the binding substance here being the desired holistic focus for continuous improvement, which is the unified interface between hard and soft systems. It takes a holistic view that the people, data and overall goal of improved quality within a system are equally interrelated, and growth must be even in all directions, a notion somehow lost in translation in previous efforts.

The application of Six Sigma in a variety of industries is well documented in the literature. Examples in the manufacturing sector include Motorola and GE (Pande *et al.*, 2000) as the most famous, while it has also had success in the construction industry (Stewart and Spencer, 2006) and accounting practices (Brewer and Bagranoff, 2004). A current shift in literature is focused on the application of Six Sigma principles in the service sector (Sehwail and Deyong, 2003; Antony, 2006; Chakrabarty and Tan, 2007).

The importance of identifying key performance metrics is a recurring theme in the literature. Antony (2006) emphasises the importance of aligning projects to business objectives, and in agreement with Sehwail and Deyong (2003), reflects that the definition of Six Sigma as a quality measure must be taken in context for service industries. For example, "a defect may be defined as anything which does not meet customer needs or expectations. It would be illogical to assume that all defects are equally good when we calculate the sigma capability of a process" (Antony, 2006, p. 246). In other words, there is so much possible variation in the customer response, it is difficult to fit them in the constraints of whether they are merely a defect or not.

On reflection, Six Sigma as a quality management approach, irrespective of industry or application, can be seen to have brought many positive elements to continuous improvement. Factors such as management commitment and open communication are essential for successful implementation as with any attempt at continuous improvement. In answer to this, it can be said that Six Sigma provides a clear focus on measurable financial returns through a sequential and disciplined manner, and establishes an "infrastructure of champions" with its training style of introducing "belt" qualifications (green, black, master black belts, etc.) within the organisation to lead the way in data-driven decision making for improvement efforts (Antony, 2004).

However, for all of its supposed benefits, there are also a number of disadvantages that must be addressed for it to become a sustainable improvement technique, and not end up meeting a similar fate to its predecessors, and becoming just another "management fad" that fades away when it has grown out of favour. First of all, the training for and solutions put forward by Six Sigma can be prohibitively expensive for many businesses, and the correct selection of improvement projects is critical (Senapati, 2004). Antony (2004) discusses the non-standardisation of training efforts (in terms of belt rankings, etc.), and how this accreditation system can easily evolve into a bureaucratic menace, where time and resources are misspent focussing on the number of "belts" within the organisation, and not the performance issues at hand. Although the belt system is an attempt to develop "in-house" expertise, as with any business improvement approaches, techniques or philosophies, Six Sigma also faces a real danger of becoming lost in a consultancy practice, being oversold and incorrectly used, in a similar way to TQM. The relationship between Six Sigma and organisational culture has not been explored in the literature surrounding the subject (Antony, 2004), and it is essential that this gap is bridged so that the true potential of a comprehensive cultural improvement philosophy underpinned by a data-driven scientific approach is unlocked.

TQM was a profound, all-inclusive philosophy that presented huge potential to transform the way in which businesses of all disciplines were managed. However, this is also where the inherent weakness of TQM lies – the fact that it is only a "philosophy". Six Sigma moves beyond this view, and has recognised that organisations need direction in their efforts to achieve improvements, structuring the concepts and philosophical ideas provided by Deming into a methodology that can be followed to obtain process improvements. Six Sigma has answered the critics of TQM by associating quality improvement with specific business metrics, leading organisations to quantify any improvement made in performance terms. In conclusion, Six Sigma has succeeded in bringing the necessary expertise back into the firm through its strict accreditation process of sequential "belts" (green, black, master black belt, etc.), and although expensive to train and implement, has at least brought about the recognition from practitioners that eluded TQM.

As with all avenues of process improvement, however, it is critical that philosophy is aligned with scientific knowledge. Six Sigma has long been seen as a statistics-heavy, technical approach to process control. In order to prevent it becoming another "myopic revolution" of improvement approaches, we must learn from our past mistakes, and ensure that the wider philosophy behind the structured technicalities of Six Sigma are recognised and acknowledged. In other words, we must not fail to recognise that without managing people correctly, or training new recruits, any technical improvements made to the processes will not be sustained.

6. The integration of lean and Six Sigma

The phrase "lean Six Sigma" is used to describe the integration of lean and Six Sigma philosophies (Sheridan, 2000). There is little literature available on the integration of these concepts when looking for a "common model, theoretical compatibility or mutual content or method", (Bendell, 2006).

The concept of lean Six Sigma as an approach to process improvement has yet to fully mature into a specific area of academic research (Bendell, 2006). It can be said that in practice the majority of efforts to fully and comprehensively implement a lean Six Sigma initiative to its full potential have not been realised (Smith, 2003). This failure to sustain a change towards continuous improvement can be attributed for one, to the lack of commitment from management (Cusumano, 1994; Kotter, 1995). Specifically, in the case of fusing lean and Six Sigma, the two approaches have often been implemented in isolation (Smith, 2003), creating lean and Six Sigma subcultures to emerge within the organisation, which can cause a conflict of interest and a drain on resources (Bendell, 2006).

Six Sigma complements lean philosophy in as much as providing the tools and know-how to tackle specific problems that are identified along the lean journey: "Lean eliminates 'noise' and establishes a standard" (Wheat *et al.*, 2003, p. 44).

Six sigma focuses project work on the identified variation from the proposed standard, which in itself does not entirely focus on the customer requirements, instead it is sometimes a cost-reduction exercise (Bendell, 2005) that can lose sight of the customer if not implemented alongside lean.

Similarities can again be drawn between lean and Six Sigma, and the need for a culture of continuous improvement operating at all levels within an organisation. Arnheiter and Maleyeff (2005) take this discussion further in their work on the integration of lean and Six Sigma, and outline the benefits of such a consolidated approach. For example, providing lean with a more scientific approach to quality, so that through the use of control charts, processes can be kept on target, effectively reducing waste incurred through faulty processing.

Table I summarises the key lean implementation steps, along with the Six Sigma tools that can be used as an aid to achieve each task. It can be seen here, that lean and Six Sigma are ideally suited to be used in a comprehensive methodology incorporating

Table I.
Synergies between lean and Six Sigma

Lean	Six Sigma
Establish methodology for improvement	Policy deployment methodology
Focus on customer value stream	Customer requirements measurement, cross-functional management
Use a project-based implementation	Project management skills
Understand current conditions	Knowledge discovery
Collect product and production data	Data collection and analysis tools
Document current layout and flow	Process mapping and flowcharting
Time the process	Data collection tools and techniques, SPC
Calculate process capacity and Takt time	Data collection tools and techniques, SPC
Create standard work combination sheets	Process control planning
Evaluate the options	Cause-and-effect, FMEA
Plan new layouts	Team skills, project management
Test to confirm improvement	Statistical methods for valid comparison, SPC
Reduce cycle times, product defects, changeover time, equipment failures, etc.	Seven management tools, seven quality control tools, design of experiments

Source: Adapted from Pyzdek (2000)

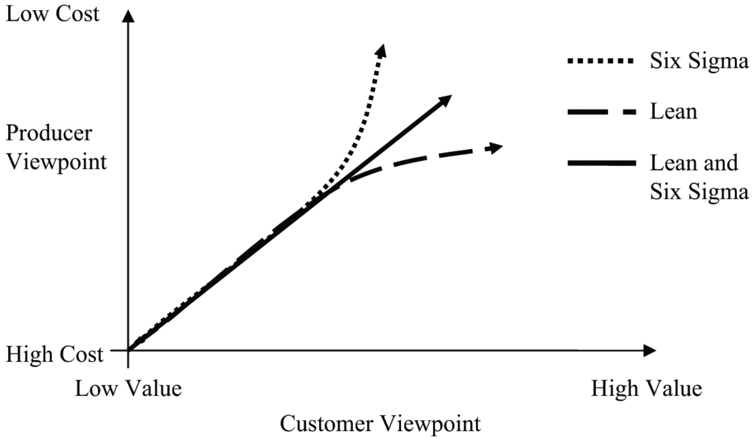
the key elements of both, as each stage can gain from the respective techniques, both following the Six Sigma road map of define, measure, analyse, improve, control.

The integration of lean and Six Sigma aims to target every type of opportunity for improvement within an organisation. Whereas Six Sigma is only implemented by a few specific individuals within a company, lean levels the empowerment and education of everyone in the organisation to identify and eliminate non-value adding activities (Higgins, 2005). The integration of the two methodologies attempts to provide empowerment even at the higher-level process analysis stages, so that employees have true ownership of the process. If the two are actually implemented in isolation, the outcome can result in neither being done effectively; constrained by one another's needs in the organisation (Harrison, 2006). Again, it could even create two subcultures within the organisation, competing for the same resources, etc. (Smith, 2003).

When implemented as a stand-alone philosophy, there is a limit to the scope and size of improvements achieved through the application of lean principles. Antony *et al.* (2003) suggest that this "ceiling" of improvement is reached because the strategy used for improvement depends on the problem trying to be solved, and therefore must be aligned to achieve effective results. Antony *et al.* (2003) go on to suggest that this is a result of lean principles lacking a directed, cultural infrastructure as can be seen with the Six Sigma approach. This is a theme continued by Sharma (2003), who argues that Six Sigma methodologies should be used to help drive the implementation of lean efforts in an improvement initiative, as it can be difficult to establish any sort of momentum when attempting to extend the philosophy throughout the organisation or supply chain. Hence, these efforts need to be directed by a strong approach that is capable of maintaining direction and focus within the business.

Both approaches have the same end objective, i.e. to achieve quality throughout, whether it is customer service, the product, the process or training and education of the workforce. They are effective on their own, but organisations may well find that after initial improvement, they reach a plateau; and find it difficult to create an ongoing culture of continuous improvement (Arnheiter and Maleyeff, 2005). To overcome this, the lean approach must integrate the use of targeted data to make decisions and also adopt a more scientific approach to quality within the system. Six Sigma, on the other hand, needs to adopt a wider systems approach, considering the effects of *muda* on the system as a whole; and therefore quality and variation levels (Arnheiter and Maleyeff, 2005). Figure 2 shows how each approach can gain from being seen as a single framework, and also the balance that may be reached if effectively brought together. This is a key concept for the integration of the two continuous improvement approaches, as a state of equilibrium needs to be achieved between the two, moving away from a blinkered approach in any one direction, risking becoming too lean and therefore rigid in responses to the market and subsequently impacting on value creation. The other extreme is to concentrate too much on reducing variation beyond the requirements of the customer, and therefore wasting unnecessary resources in the pursuit of zero variation. The balance lies in creating sufficient value from the customer's viewpoint, so that market share is maintained, while at the same time reducing variation to acceptable levels so as to lower costs incurred, without over-engineering the processes.

The integration of lean Six Sigma is not perceived by everyone to be an effective meeting of approaches. There is some criticism in the literature regarding the blending of the two approaches. Perhaps the most critical is Bendell (2006), who has extensive



Source: Arnheiter and Maleyeff (2005)

Figure 2.
Competitive advantage of lean, Six Sigma and lean Six Sigma (Source: Arnheiter and Maleyeff, 2005)

experience as both practitioner and academic in this field. He argues that lean and Six Sigma have become "ill defined philosophies" (Bendell, 2006, p. 258), resulting in their dilution as effective tools due to "relatively obscure [. . .] company specific training programmes" (p. 258), going as far to say that "the alleged combination is no more than a philosophical or near-religious argument about professed compatibility of approaches" (p. 255). However, Bendell does go on to suggest that it would be beneficial for all if a single approach that effectively brought the two philosophies together was available.

These views reinforce the fact that although there appears to be a number of consultancy models for lean Six Sigma freely available on the internet by consultants, the presented methodologies are put together without logical explanation (Bendell, 2006) and more importantly, with no theoretical underpinning or explanation for the choice of techniques.

Spector and West (2006) take the view of the practitioner, pointing out that when adopting lean/Six Sigma, practitioners can find themselves commencing a large number of projects that yield insufficient results for the amount of time needed to complete them. In stark contrast, Mika (2006) takes the stance that the two approaches are completely incompatible with one another because Six Sigma cannot be embraced by the "average worker on the floor" (Mika, 2006, p. 1). He argues that lean is accessible by these workers, and encourages effective teamwork through collaboration and participation through cross-functional teams.

Lean in itself does not address all of these criteria. Through the application of Lean techniques, significant changes can be made without this deep understanding of the system. However, this can lead to instability. If only lean techniques are applied, it would take too long to develop the necessary depth of understanding to take forward the improvement initiative, something that can also be viewed as a contributing factor to the unsustainable nature of many lean initiatives.

The application of lean tools and techniques identifies key areas that can be leveraged by Six Sigma techniques. It is also necessary to configure the information flow to best drive the system, providing continuous feedback.

Lean techniques are also used to consider and improve the organisation on an operational level, reducing complexity and interactions within the system, through the targeted removal of non-value adding activities. From this reduction in complexity, Lean identifies opportunities for improvement that can then be leveraged through the application of high powered, more focused, Six Sigma techniques, driving the improvement of the system further towards a lean environment.

Figure 3 illustrates this integration of lean and Six Sigma, and how both strategic and operational improvement is achieved

The key considerations based on this literature when constructing a new and a comprehensive framework for lean Six Sigma, are:

- it needs to be strategic and process focused;
- the framework should be balanced between the two philosophies to harness the recognised advantages of both;
- a balance between complexity and sustainability must be reached; and
- it should be structured around the type of problem experienced.

Going one stage further than this is to develop an industry-specific framework.

In terms of successful lean Six Sigma efforts, Smith (2003) outlines two case studies that experienced impressive results from a combined approach to improvement. The first case study had been practising lean for approximately 18 months when consultants were called in to push the improvements further. However, both case studies found that one of the two approaches became dominant in the improvement process. A fully integrated framework targeting specific industries will take away any such ambiguity over which techniques to apply where and in what situations.

Sharma (2003) also describes the benefits of using Six Sigma techniques in conjunction with lean, whereby strategic improvement goals are established by the company's leaders, and then a process of quality function deployment (QFD) is used to prioritise the project work. Although effective in this implementation, there is no comprehensive framework present that specifically integrates lean and Six Sigma concepts through an implementation roadmap. The QFD approach can also be viewed as a more complicated approach to the selection of continuous improvement tools.

The work of George (2002) can be seen to lead the exploration of lean and Six Sigma techniques, providing the benchmark work for future researchers. Following on from

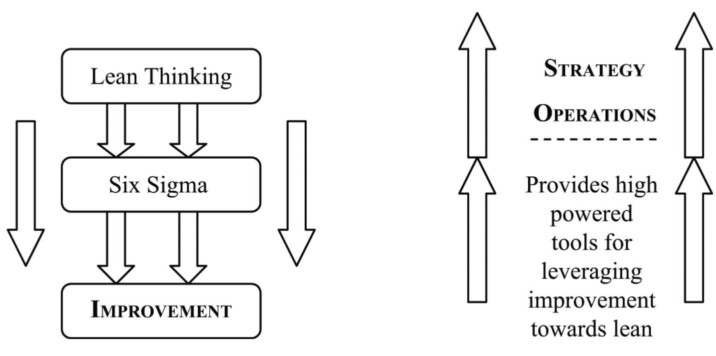


Figure 3. Integrating lean and Six Sigma

this, one of the most comprehensive examples of research into this area is the work of Kumar *et al.* (2006), who have integrated some key lean techniques with the Six Sigma framework for implementation at an Indian SME. The approach taken was to develop a lean Six Sigma framework around the problems identified at the organisation, which, while effective, may well be beyond the reach of most practitioners working under strict time and other resource constraints as discussed earlier. Some key points are made from this work:

- there is no standard framework for lean Six Sigma;
- there is no clear understanding concerning the usage of tools, etc., within the lean Six Sigma frameworks; and
- with the framework presented, there is no clear direction as to which strategy should be selected at the early stages of a project (Kumar *et al.* 2006).

These points present key questions to be answered when considering the construction of an effective lean Six Sigma framework. Figure 4 illustrates how both lean and Six Sigma can be integrated together to form a coherent management tool for business process improvement. Lean philosophy underpins the framework, providing strategic direction and a foundation for improvement, orientating the general dynamics of the system by informing the current state of operations. From this, lean thinking identifies key areas for improvement ("hot spots"). Once these hot spots have been identified, Six Sigma provides a focused, project based improvement methodology to target these hot spots and ultimately drive the system towards the desired future state.

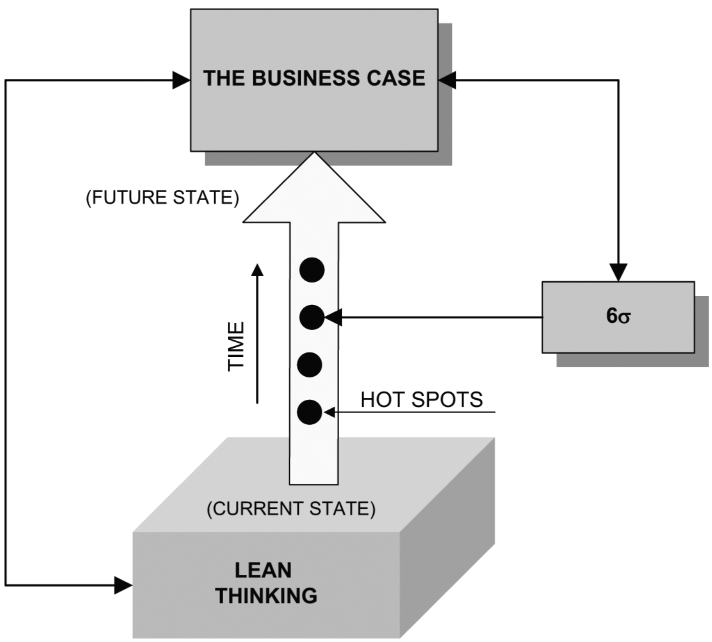


Figure 4.
Conceptual model for lean Six Sigma

7. Conclusion

It can be seen that the business improvement philosophy of lean thinking and the more scientific improvement paradigm of Six Sigma have experienced success in a wide ranging spectrum of industries. The two paradigms are influential catalysts of change as stand-alone methods, but more provokingly, if fused together, can potentially represent an exceptionally powerful tool. Aligning the cultural aspects of Lean with the data driven investigations of Six Sigma holds huge potential in a bid for a genuine and sustainable approach to organisational change and process improvement.

Much of the inherent mistrust surrounding lean as a philosophy is due to the limited and myopic way that it has been implemented. For example, reducing inventory levels cannot be enforced in volatile environments, usually leading to even greater variability and exposure to risk. Therefore, a systematic approach needs to be adopted which optimises the whole system and focuses the right strategies in the correct places.

It is important to recognise that lean has moved away from being a one-stop cure all philosophy. Instead, lean Six Sigma should be seen as the platform for the initiation of cultural and operational change, leading to total supply chain transformation. When used in combination with other complimentary continuous improvement techniques such as Six Sigma, lean provides leverage for comprehensive strategies and therefore provides a more integrated, coherent and holistic approach to continuous improvement. Lean must be viewed, understood, and accepted as a coherent methodology and therefore a step beyond previous *ad hoc* continuous improvement strategies.

Lean Six Sigma should be seen as a precursor to producing more responsive supply chains through effective communication leading to strategic alliances and visibility. Organisations will need to be as lean as possible, providing clarity for the implementation of Six Sigma techniques, moving forward to additional concepts such as agility and total supply chain integration. This is not to say that every element of the lean philosophy or Six Sigma approach should be adhered to, as not every lean tool or technique is suitable for every situation or company.

In conclusion, if lean is implemented without Six Sigma, then there is a lack of tools to leverage improvement to its full potential. Conversely, if Six Sigma is adopted without lean thinking, then there would be a cache of tools for the improvement team to use, but no strategy or structure to drive forward their application to a system.

Although lean and Six Sigma (to a certain extent) evolved independently, there are a number of encouraging articles discussing the use of an amalgamated approach. However, in order to drive a unified methodology forward, a closer integration of the two approaches must be achieved, with significant scientific underpinning to provide a sound theoretical foundation (Pepper, 2007).

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