Six Sigma and Lean Manufacturing- A Merger for Worldclass Performance, but is it Really Talking Place?

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More than a decade after their development and first wave of deployment, Six Sigma and Lean Manufacturing have recently returned on the corporate agendas of a larger number of corporations across industries and supply chains. In the wake of their re-surge, this commentary addresses the evolution, context, content and deployment patterns of the two distinct management concepts. It also analyses claims in the business press that a merger is taking place between Six Sigma and Lean Manufacturing. Here, it is found that there is not enough evidence to broadly support such claims, and it is only concluded that there is some evidence of an early tend towards a merger and that a possible merger would have many synergies and advantages. Finally, an example from a Scandinavian manufacturing company is provided that explains how Six Sigma and Lean Manufacturing can be used in a beneficial way for companies to reach world-class performance.

Key words & phrases: Six Sigma, Lean Manufacturing and Continuous Improvement.

The Financial Times defines a Six Sigma initiative as "a programme aimed at the near-elimination of defects from every product, process and transaction" (Tomkins, 1997). Mike Harry, one of Six Sigma's pioneering contributors states: "An aggressive campaign to boost profitability, increase market share, and improve customer satisfaction has been launched by a select group of leaders in American industry.

Known as 'Six Sigma', the strategy provides companies with a series of interventions and statistical tools that can lead to breakthrough profitability and quantum gains in quality, whether a company's products are durable goods or services" (Harry, 1998: 60). Today, it is by a growing audience regarded as the "Koh-i-Noor diamond, the Rolls-Royce, the Veuve Cliout of quality programmes"

(Murdoch, 1998: 53).

Lean Manufacturing was first coined and defined in 1990 in the book 'The Machine That Changed the World' (Womack, Jones and Roos, 1990; 13-14), which is based on a five-year international study of the automotive industry. "Lean Production (a term coined by IMVP researcher John Krafcik) is 'Lean' because it uses less of everything compared with mass production - half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time."... Mass-producers set a limited goal for themselves-'good enough',... Lean producers, on the other hand, set their sights explicitly on perfection" (Womack et. al., 1990; 13-14). According to Taylor and Brunt (2000: 1), "a succession of firms around the world have improved their performance by the application of Lean principles and approaches".

In the first part of this paper, we trace the evolution and deployment of Six Sigma and Lean Manufacturing, also describing the context in which they were fist launched alongside their main content. The second part of the paper discusses the synergies and advantages of a possible merger between Six Sigma and Lean Manufacturing, then lists evidences for and against a possible merger taking place between the two concepts, before evaluating if other concepts are also moving closer to Six Sigma and Lean Manufacturing. In the final part of the paper, a case study from an international company is provided that explicitly explains how Six Sigma and Lean Manufacturing is used together in a pragmatic and powerful programme for continuous improvement.

THE EVOLUTION OF SIX SIGMA

Although Six Sigma was developed and launched by Motorola in the mid 1980s, its real origin can be tracked back to the 1920s. More specifically to the work of Walter A. Shewhart at Bell Telephone Laboratories (Bell Labs), the research entity of Western Electric Company. According to Butman (1997: 20) Western Electric and its major plant, The Hawthorne Works, enjoyed in the 1920s the position as sole supplier of millions of phones and their equipment to the burgeoning Bell System. Juran (1989: 4) explains how "the Bell System was at that time facing some massive quality problems which its sister industries were not to face until decades later, a bewilderingly complex system; unprecedented interchangeability of mechanical apparatus and electrical circuitry; extremely close tolerances of manufacture

and measurement; severe requirements for reliability and maintainability" (Butman, 1997: 24). Interestingly, the manufacturing of interchangeable parts with tolerances was first systematically introduced in the American armour industry in the late 19th century (Provost and Norman, 1990).

At Bell Labs, a group of scientists lead by Walter A. Shewhart, sought in the 1920s to develop a mathematically oriented theory of sampling and inspection, with a major focus on how best to reduce manufacturing variation. Reducing variation would have a direct impact on the plus-20-percent defect rate at Hawthorne which would help reduce costs, improve productivity and quality and reduce failures in the field (Butman, 1997: 33-34). In May 1924, Dr. Shewhart described in a one-page memo to his boss a new device, the control chart, that he thought might help solve some of the challenges. Shewhart (1939: 2-3) explains that this may "be taken as the starting point of the application of statistical technique in the control of the quality of a manufactured product" (Shewhart, 1939: 4).

In terms of application of the new concept, Quality Control, Butman (1997: 37-38) states that it had a limited impact, event at Western Electric Company. During the Second World War the US War Department had its own Quality Control section, but according to Juran (1989: 7) the surge in quality control activities in the allied countries soon stalled, as the application had become "...tool oriented rather than result oriented". Rather it was parts of the Japan industry that pioneered a broad application of Quality Control in the wake of the Second World War (e.g., Kondo, 1994: 35-37; Garvin, 1988: 183-188; Kilian, 1992: 29-47). In 1968 Japanese quality professionals introduced the term "Companywide Quality Control" (Ishikawa, 1985: 91), to specify the unique Japanese companywide integration of quality control practices, including continuous improvement, customer orientation, and involvement of all employees through QC circles (Garvin, 1988: 190-191).

The electronics industry was among the industries were Japanese manufacturers managed to gain strong industrial market shares in the 1960s and 1970s. According to Henkoff (1989: 164) Motorola first became aware of the threatening situation in 1978 at a strategy session where a sales executive by the name of Arthur Sundry ventured the opinion that Motorola was in danger of being buried by the Japanese on quality. The context at Motorola was an organisation with massive quality problems, products and processes of ever-increasing complexity, close tolerances of manufacture, and severe requirements from customers for reliability and maintainability. First in 1981 did

Motorola set a goal of a ten-fold improvement in quality in five years, along with a sharpened focus on the customer (Bhote, 1989: 366; Hughes, 1991: 64).

By the mid 1980s Motorola realised that a ten-fold improvement was inadequate in benchmark with key competitors of Japanese origin who enjoyed a performance of a thousand times fewer defects (e.g., Bhote, 1989: 368; Henkoff, 1989: 168). Based on visits by the top management team of Motorola to Japan and a document prepared by the Communication Sector, Motorola's main manufacturing plant termed "Six Sigma Mechanical Design Tolerancing", the road ahead became clear. After some internal pilot implementations, the chief executive officer of Motorola, Robert Galvin, formulated in 1987 the goal of "achieving Six-Sigma capability by 1992" in a memo to all Motorola employees (Bhote, 1989: 368). The Motorola Six Sigma programme focused heavily on improvement projects to continuously reduce variation in both manufacturing and non-manufacturing processes, and to improved design of processes and products to make these insensitive to variation, i.e. robust. Comprehensive training programmes were launched to deploy the Six Sigma improvement methodology throughout the company, with special emphasis on tools such as the Seven Quality Control Tools and Factorial Experiments (Bhote, 1989: 371). Motorola ran the Six Sigma programme in parallel with four other closely linked strategic initiatives for Total Customer Satisfaction: Total Cycle Time Reduction, Product and Manufacturing Leadership, Profit Improvement, Participate Management (e.g. Lahiri, 1999; Magnusson, Kroslid and Bergman, 2000: 64-66).

By 1989 Motorola was reaping significant financial reward, with estimates such as savings of $480 million from a total of $9.2 billion in sales, and a return of investment ration of 29:1 in terms of training costs (e.g., Bhote, 1989: 372; Cook, 1990: 62). By 1992, Motorola had almost reached it targets and according to "George Fisher, the then chief executive officer of Motorola" "We've reached the Six Sigma target in many areas, but not as a company. Right now, manufacturing is probably around Five Sigma." (Donlon, 1993: 52).

In the wake of the successes at Motorola, other dominant players in the electronics industry launched Six Sigma initiatives on their own in the early 1990s, including Digital Equipment, Eastman Kodak, IBM, Raytheon, and Xerox (e.g., Hendricks and Kelbaugh, 1998: 48; Rifkin, 1991: 61; Smith and Oliver, 1992: 72; Whiting, 1990: 55). According to Magnusson et. al. (2000: 15-16, 41-42), it was first in the mid 1990s that Six Sigma disseminated to a large industry base, with the launch of Six Sigma

programmes in ABB, Allied Signal and General Electric. These companies further refined the content of Six Sigma, including a stronger focus on the bottom line and top line contributions, tougher training courses and stronger involvement of stakeholders as well as an advancement and expansion in the application of statistical tools (Harry, 1998: 62; Magnusson et. al. 2000). The bottom line results of the improvement projects and the visible top management commitment of ABB, Allied Signal and General Electric largely sparked the strong horizontal deployment into different industries, countries and continents, as well as the strong vertical deployment to first- and second-tier suppliers that Six Sigma currently enjoys.

LEAN MANUFACTURING

According to Jones (2001: 17) the origin of Lean Manufacturing has a long history. The key Lean principles of linking every value-creating step in a continuous sequence was evident in the US armoury industry around 1850 (Hounschell, 1984: 3). Jones (2001: 17) explains how the logic of the principle of having every machine lined up in process sequence reached its peak in Henry Ford's first large assembly plant in Highland Par in 1915, making the famous Model T. It was Henry Ford who coined the term "Flow Production". Already by 1908, Ford had achieved almost perfect part interchangeability, as opposed to filing and adjusting parts, and made the assembler perform only a single task and move from vehicle to vehicle around the assembly hall (Womack et. al., 1990: 20). Productivity went up significantly, and was further enhanced with the introduction of the moving assembly line in 1913, bringing the cars past stationary workers.

In the 1920s, however, industrial history took a different direction. Customers wanted more choice and product variety than Flow Production allowed for, and the automobile manufactures decided instead to organize their production process by separate departments specializing in different activities. Instead of following the product flow, batches of different products would wander from department to department, with inventories of work-in progress between. Henry Ford followed this route in his next major plant in Rover Rouge in 1931, and the age of what he called "Mass Production" began. Mass Production worked well when demand grew rapidly - and everyone could sell every car they made, but upon market saturation the long lead times and costly inventories began to surface (Jones 2001: 17-18).

In Japan, the founders of Toyota, Sakichi

Toyoda lead the work on their own version of "Flow Production" in the 1930s. It was here that the two key principles of machine-and-line stopping and a just-in-time pull system was formulated, later to be followed by initiatives to level the workload (e.g., Cusumanu, 1985; Jones 2001: 20). These principles were first linked an put into operations after World War II by Taiichi Ohno, the production chief at Toyota, attributed for pioneering and implementing the Toyota Production System (see also Spear and Bowen, 1999). At that time Toyota's started its quest for growth with many contextual challenges, including a tiny domestic market, a work force that wanted involvement, scant investment opportunities and a broad range of different car models. Toyota's response was to group workers into teams each with a set of assembly steps and with a team leader, empowered to the team the job of housekeeping, minor tool repair, quality control and continuous process improvement (Monden, 1993; Womack et. al., 1999: 55-56). The Toyota Production System became a think-thank for content developments, with such strategies, methodologies and tools as the 5WHYs, 5Ss, Poka Yoke and Single Minute Exchange of Die (e.g., Hirano, 1995; Ohno, 1988; Shingo, 1981). The Toyota Production System was impressively effective, with rework, cycle times and work-in progress continuously driven down (Womack et. al, 1990:63). Integration was key at Toyota; product development was integrated with process and industrial engineering, and the supply chain was integrated by making suppliers and dealers a part of the production system as well as producing cars to customer orders and preferences. Womack et. al. (1990: 68) judges that Toyota "had fully worked out the principles of Lean production by the early 1960s". The dissemination of the Toyota Production System was largely limited to parts of the Japanese industry, with unequal proficiency.

In 1990 results of a five-year study of the world's automobile manufacturing industry by researchers at the Massachusetts Institute of Technology was published by Womack et. al. (1990). The study revealed strong evidence that the Japanese automotive manufacturers and in particular Toyota were significantly ahead of established American and European car manufacturers in key areas such as productivity, quality, space, inventories and training of workers. The results were broadly published, and became a dominant issue, first within the confines of the automotive industry, but later also in a broader range of manufacturing industries. According to Taylor and Brunt (2001: 1) Lean principles and approaches spread to a succession of firms in the US and Europe, with a strong focus on reducing cycle times,

waste and improving the design of processes with respect to flow. In many texts on Lean manufacturing, there is a strong focus on waste reduction, which can be seen as the cause of poor cycle times, waste and process flow design (e.g., Rother and Shook, 1998; Sheridan, 2000: 81). Over the years the tools and methodologies have been refined, with qualitative mapping tools such as flow charts, supply chain matrix, red-tagging, and process activity mapping (Heins and Rick, 2001). Taylor and Brunt (2001: 1) state that "we have seen examples where throughput times and defects have been cut by 90 per cent, inventories reduced by three-quarters and space and unit costs slashed in half".

IS THERE A MERGER?

This section discusses the synergies and advantages for a possible merger between Six Sigma and Lean Manufacturing. It then moves on to list evidences for and against the merger really taking place, followed by thoughts on similar consolidation opportunities for other related management concepts are shared.

The synergies and advantages of a merger between Six Sigma and Lean Manufacturing contain some interesting aspects. First, the two concepts would bring together two fields of management theory, with Six Sigma having developed from the field of Quality Management and Lean Manufacturing from Manufacturing Management. This is positive from a range of perspectives, and would offer unique opportunities. The management discourse of today is, for example, full of criticism for the management concept "jungle" (e.g., Redding, 1994). Here consolidations and mergers would undoubtedly reduce complexity and make it easier for all layers of the organisation to differentiate among the concepts. Second, although the industrial contexts in which Six Sigma and Lean Manufacturing developed were different, i.e. electronics industry and automotive industry, there were many similar contextual aspects, including interchangeability of parts, complexity of systems and need for greater customer satisfaction (e.g., Butman, 1997: 33-38, Harry, 1989: 60, Womack et. al., 1990: 64-68). Third, the rationale of both Six Sigma and Lean Manufacturing can at least to some extent be said to reside in customer satisfaction (top line) and cost efficiency (bottom line) of organisations (see e.g., Harry, 1998: 60, Magnusson et. al., 2000: 41-42, Womack et. al. 1990: 13-14).

Fourth, from the review of the historical development of Six Sigma and Lean Manufacturing it can be derived that both concepts are profoundly based on continuous improvement, as opposed to concepts based

on deterministic assumptions within the same field of management. Czarnecki (1998) argues that Six Sigma has made chief executive officer's realise "the importance of understanding variation and its sources, and working continually reducing it until processes are in a stable, financially beneficial state." Womack et. al. (1990: 3) argues that "mass producers set a limited goal for themselves - 'good enough',... Lean producers, on the other hand set their sights explicitly on perfection: continually declining costs." According to Giroux and Landry (1998: 194) most fields of management theory encompass different schools of thought through their various concepts. They add "it is for this reason that certain approaches simultaneously advocate both continuous improvement and do it right the first time... without concern for the coherence for the resulting message". In the case of Six Sigma and Lean Manufacturing, both concepts can be related to a school of thought based on continuous improvement as opposed to more deterministic schools of thought.

Fifth, Six Sigma and Lean Manufacturing have a complementary focus of improvement, even a complimentary set of tools. At the launch of Six Sigma at Motorola the key focus of the improvement efforts were on variation reduction and designing products and processes so that they become insensitive to variation, i.e. robust (Bhote, 1989: 367-368; Harry, 1998: 60, Lahiri, 1999). In Lean Manufacturing the focus was more on improving cycle time, resource utilisation and process flow design, often just addressed as waste reduction (e.g., Rother and Shook, 1998; Sheridan, 2000: 81, Womack et. al., 1990: 55-63). Design is common for both concepts, but it is two types of design that are referred to, design of robust processes in Six Sigma and design of processes with efficient flow in Lean Manufacturing. Already from the start of Six Sigma at Motorola, there has been a strong link to cycle time reduction. According to Bhote (1989: 367) the Total Cycle Time Reduction programme at Motorola in the late 1980s was "closely related to the Six Sigma" programme. Looking at Toyota and its production system, Ohno (1988) explains how the whole system is based on three MUs; Muda ("waste"), Mura ("variation"), Muri ("stress"). The two latter MUs have not been widely published compared to Muda which was put at the forefront of Lean Manufacturing. In Spear and Bowen (1999) it is explained how the three improvement foci together form the powerful Toyota Production System. Not only the improvement foci, but also the tools that support the improvement projects seem to complement each other. In Six Sigma statistical tools dominates, whereas Lean

Table 1 Summary of the synergies and advantages of a merger between Six Sigma and Lean Manufacturing.

	Six Sigma	**Lean Manufacturing**
Company of origin	Motorola	Toyota
Industry of origin	electronics	automobile
Management field	Quality Management	Manufacturing Management
Historical basis	Quality Control at Western Electric Company	Flow Production at Ford Motor Company
Underlying philosophy	Continuous improvement	Continuous improvement
Improvement foci	Variation and robust design	Waste and flow design
Improvement tools	Seven Quality Control Tools Factorial Experiments Regression Analysis	Flow Charts Process Activity Mapping Supply Chain Matrix Red-tagging (5S)

Manufacturing is dominated by quantitative mapping tools. Together they form a broad and strong set of tools for improving process performance, with respect to cycle time, variation, resource utilisation and design.

Summing up, the above analysis of the synergies and advantages of a possible merger between Six Sigma and Lean Manufacturing can be judged as strong (Table 1), and already from their origins at Motorola and Toyota they were in essence closely related.

Having assessed the synergies and advantages of a possible merger between Six Sigma and Lean Manufacturing, we should evaluate the extent to which such a merger is actually taking place in industry. There are some of evidences that can be found both for and against.

For

· Under the headline "Lean Sigma Strategy", John H. Sheridan explains in Industry Week, October 2000, how a former GE plant in Fort Wayne, Indiana, now owned by UK-based BAE Systems PLC was one of the very first to blend Six Sigma and Lean Manufacturing tools and principles in 1997. "Over time the plant staff recognized a high level of synergy between Lean Manufacturing initiatives and the Six Sigma quality program launched while still in the GE fold" (Sheridan, 2000: 81-82).

· Annual reports from GE for 1999 and 2000 reveals that they have been very successful at integrating Lean Manufacturing tools and techniques in their Six Sigma strategy. In some cases increasing (GE, 1999; GE, 2000).

• Leading Six Sigma consulting organisations, first the Air Academy Associates, started marketing Lean Manufacturing as part of their Six Sigma training in second half of 2000 (Quality Progress, 2000; Quality Progress, 2001).

• Some text books have included comments on a gathering of principles and practices between Six Sigma and Lean Manufacturing (e.g. Bicheno, 2000, Magnusson et. al., 2000).

• In the management discourses of at least Scandinavian countries, the UK and the US there are currently a discussion about how to integrate Six Sigma and Lean Manufacturing.

Against

• The vast majority of Six Sigma consulting bodies still market seminars and courses explicitly focusing on Six Sigma methodologies and practices.

• The vast majority of Lean Manufacturing consulting bodies still market seminars and courses explicitly focusing on Lean Manufacturing methodologies and practices.

• There is no mentioning of Six Sigma in key conference events within Lean Manufacturing, see for example the 7th Annual Lean Manufacturing Conference, April 30-May 2, 2001.

• Most text books on Six sigma and Lean Manufacturing, even newly published ones, do not have reference to tools, methodologies and practices in the other concept (e.g., Taylor and Burnt, 2001; Breyfogle, 1999; Pyzdek, 1999).

• Many companies still run Six Sigma programmes or other Quality Management initiatives focusing on variation and robust design, and separately apply Lean Manufacturing or other Manufacturing Management initiatives focusing on cycle time and resource utilisation.

Based on the evidences for and against a merger taking place between Six Sigma and Lean Manufacturing as well as a general literature review, a number of interesting topics arise. One is that it seems as if the refinement of the Six Sigma concept over the last year has lead to an inclusion of Lean Manufacturing tools and methodologies. The refinement of the Lean Manufacturing concept, however, does not seem to have embodied Six Sigma tools and methodologies to the same extent. Another issue, is that the literature have only documented an integration of Six Sigma and Lean Manufacturing practices in a very small number of a companies, including GE (e.g., Magnusson et. al., 2000: 43, Sheridan, 2000: 81-82). This, however, can be interpreted as a early trend taking into account the pioneering role of GE in a broad range of management concepts. That consulting bodies also market courses with both Six Sigma and Lean

Manufacturing seminars supports this early trend. A third issue is that the main texts books on Six Sigma as well as on Lean Manufacturing seemingly fail to recognise the similarities, complementary elements and synergies with other management concepts. In text books such as Taylor and Burnt (2001), Breyfogle (1999), Pyzdek (1999) there is no mentioning of other concepts that the one described. It thus seems reasonable to conclude that there has been little integration in management theory between Six Sigma and Lean Manufacturing, and that despite an early trend identified in terms of industry practice more empirical research is needed to establish more accurate answers.

We have seen how the synergies and advantages of a merger between Six Sigma and Lean Manufacturing is strong and that some early trends of a merger in terms of industry practice can be found. To stay ahead of developments it seems reasonable to use the traces of integration that has been found, to also discuss if other management concepts are moving toward Six Sigma and Lean Manufacturing. In some recent academic contributions it is argued that an integration within some fields of management is currently ongoing (e.g., Bergman and Kroslid, 2000; Giroux and Landry, 1988), i.e. Quality Management sees Quality Management System, Self-Assessment Models and Six Sigma moving closer. This discussion, however, focuses on the question if concepts within other fields of management are coming closer to Six Sigma and Lean Manufacturing. Perhaps the most relevant concept to bring into such a discussion is Total Productive Maintenance.

Total Productive Maintenance evolved in the Japanese manufacturing industry in the 1970s, and is generally viewed to belong to the field of Maintenance Management (Willmott, 1994). The concept has a strong focus on the maintenance of equipment, seeking to continuously improve the availability and costs of maintenance (e.g., Nikajima, 1989). Interestingly, Total Productivity Maintenance seem to have similar deployment pattern in the Western World as have Six Sigma and Lean Manufacturing, i.e. first wave in the late 1980s and early 1990s, with a re-surge in the late 1990s. Evaluating the synergies and advantages between Six Sigma and Lean Manufacturing, the following five aspects were addressed: (1) brings together different field of management, (2) similar industrial context, (3) the customer satisfaction and cost efficiency rationales, (4) based on continuous improvement and (5) complimentary focus and tools. In the case of Total Productivity Maintenance moving closer to Six Sigma and Lean Manufacturing it can be judged that aspects 1, 3, 4 and 5 applies well, whereas aspect 2 is not as applicable.

The reason for aspect 2 being less applicable is that Total Productivity Maintenance did evolve in a number of manufacturing industries at the same time, each with a different industrial context. Issues of the industrial context such as interchangeability and complex systems were obviously evident also in the development of Total Productive Maintenance, but not as influential as for Six Sigma and Lean Manufacturing.

There are some few evidences of a merger taking place in terms of industry practice between Total Productivity Maintenance, Six Sigma and Lean Manufacturing. For example is there a handful of Six Sigma consulting organisation that recently included subjects on Total Productivity Maintenance to their Six Sigma and Lean Manufacturing seminars. The author is also aware that some companies are discussing how to integrate the three concepts. The amount of evidences can however only be judged as fewer and weaker compared to the evidences related to Six Sigma and Lean Manufacturing alone. Contributions from the management theory are needed as well as empirical research into industry practice. Although a possible integration process is not very advanced, it can only be concluded that a further integration of Total Productivity Maintenance, Six Sigma and Lean Manufacturing would have the capacity to present a very powerful triangle for continuous improvement, with many synergies in terms of application and implementation. The traces of integration that have been found for Total Productivity Maintenance means that there could be more management concepts in other fields of management that are moving closer. Marketing Management, Human Resource Management, Knowledge Management and Controlling to mention a few.

INDUSTRY CASE ON SIX SIGMA AND LEAN MANUFACTURING INTEGRATION

In Magnusson et. al. (2000: 44-61) a framework for Six Sigma is presented, based on the Six Sigma programmes in the pioneering companies; ABB, Allied Signal, General Electric and Motorola. The framework embodies the four elements of top management commitment, stakeholder involvement, training scheme and measurement system. Stakeholders include employees, owners, suppliers and customers. At the core of the framework is a formalised improvement methodology with the following five steps: define, measure, analyse, improve and control (Figure 1).

Figure 1 The corporate framework of Six Sigma, with the four main elements and the improvement methodology (Magnusson et.

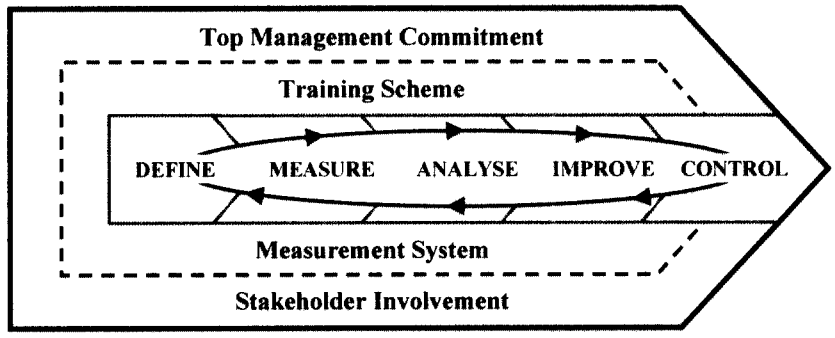

Figure 1 The corporate framework of Six Sigma, with the four main elements and the improvement methodology (Magnusson et.al., 2000: 44).

al., 2000: 44).

In this industry case reference will be made to Company X. It is an international manufacturing company with Headquarters in Scandinavia, that employs around 1000 people and has for years enjoyed good growth rates. Company X started its implementation of Six Sigma/Lean Manufacturing half a year ago, and is already experiences good results from improvement projects on variation and robust design as well as improvement projects on cycle time, resource utilisation and flow design.

The framework that Company X uses in its implementation of Six Sigma/Lean Manufacturing is very similar to the framework in Figure 1, and the elements are identical. Each element will now be analysed, first with a presentation of content from a Six Sigma initiative (based on a literature review in Magnsson et. al., 2000) followed by a discussion about the changes Company X have done to also include Lean Manufacturing. It should also be noted that Company X only terms its initiative "Six Sigma", where Lean Manufacturing principles and tools have just been made an integral part.

Top Management Commitment

Launching Six Sigma in a company is a strategic decision that needs to be taken by top management. To capture the potential of Six Sigma, it must be made a core part of the corporate strategy for cost saving and revenue growth. Although not directly active

in the day-to-day improvement projects, the role of top management as owners, project sponsors and advocates is unabated. Pragmatic management is required, not lip service, as the top management commits itself and the company to drive the initiative for several years and into every corner of the company.

In Company X the only change to the element of top management commitment resulting from the integration of Lean Manufacturing into the Six Sigma initiative was a broadening of the scope and strategy for the initiative. The top management understood that the potential of the programme was not only variation reduction and robust designs, but also improvements in cycle time, resource utilisation and flow design. A one-day top management presentation of Six Sigma and Lean Manufacturing were held before the very launch of the initiative in Company X to create interest, but also to make sure that top management knew the essentials of the two concepts.

Stakeholder Involvement

Stakeholder involvement means bringing the improvement methodology and statistical tools of Six Sigma into the hands and minds of employees, suppliers, customers - in a very wide perspective even owners and society. In order to meet the goal set for improvements in process performance and to complete improvement projects, top management commitment is not enough. The company needs active support and direct involvement from stakeholders.

Compared to conventional Six Sigma companies, the only change Company X have done is to add specifically in the rollout plan that both employees and suppliers will be trained and introduced to the principles, methods and tools of not only Six Sigma but also Lean Manufacturing.

Training Scheme

Embodied in any Six Sigma programme is a comprehensive knowledge of process performance, improvement methodology, statistical tools, project work, deployment, framework and others. This knowledge needs to be cascaded throughout the organisation and become the knowledge of the masses. There are three fairly standardised training courses in Six Sigma. Each course has a different level of detail and practical application, ranging from very basic to comprehensive. It is also common to have roles for the individuals who are involved in Six Sigma. To denote these roles, most Six Sigma companies have adapted the belt rank

system from martial arts, with White Belts, Green Belts, Black Belts, Master Black Belts and Champions.

In Company X, all members of the middle management will be given Green Belt training alongside a couple of internally recruited and full-time Black Belts. White Belts will be given an introduction course when Six Sigma/Lean Manufacturing improvement projects are carried out in their area. How Company X went about integrating the Lean Manufacturing part of the programme is best viewed in the Green Belt course. This is a four day course, where the first day is an introduction to Six Sigma/Lean Manufacturing, the second day is dedicated to Lean Manufacturing improvement tools including a cycle time simulation workshop and the third day is about Six Sigma improvement tools including a catapult simulation workshop. The fourth, and final, day is typically held three weeks after the first three days and is basically a review of the improvement projects that have been started. In the 13-day Black Belt course there is also one day of Lean Manufacturing, followed by one day later in the course with more advanced topics on Lean Manufacturing.

Measurement system

The Six Sigma framework also provides a pragmatic system for measuring performance of processes in the whole company using a single metric-defects per million opportunities (dpmo). The measurement system reveals poor process performance and provides early indications of problems to come. What is measured is the variation in critical-to-customer characteristics of processes and products. The total number of characteristics monitored over time is from 80 to 200.

Company X has not yet come to the point where it has built its measurement system. However, it has already decided that also characteristics on cycle time and resource utilisation will be included. As variation is the preferred measurement in the Six Sigma measurement system, Company X has stated that it intends to measure performance of cycle time and resource utilisation by determining the dispersion and centring of these characteristics in relation to set tolerances, just as for variation.

Improvement methodology

Six Sigma promotes one formalised improvement methodology. The methodology starts with a define phase where the process or product that needs improvement is identified. It moves on through four specific phases: measure, analyse, improve and

control. Six Sigma companies everywhere apply this methodology, as it enables real improvements and real results.

In Company X they did not make any changes to the improvement methodology, but instead assumed that it would work equally well for Lean Manufacturing improvement projects as for Six Sigma improvement projects. Based on the first couple of improvement projects the power of the merged programme has been tested, with convincing results.

CONCLUSION

This paper has found that there are some evidences to support claims that a merger is beginning to form between Six Sigma and Lean Manufacturing. However, more research is needed to make more accurate estimates of how far the merging process has come both in terms of industry practice and theory development. Interestingly, the synergies and advantages for such a merger have in this paper been assessed as strong. For example, similar origin, philosophy of improvement, rationale and complementary improvement focus. It is also notable that both Six Sigma and Lean Manufacturing has been around for more than a decade, and that both seems stronger than ever before in terms of deployment. A merger between the two is likely to further stimulate the positive developments in dissemination patterns currently enjoyed, and form a powerful solution for industry in its quest for worldclass performance.

Once that has been achieved, practitioners and researchers should also look to other fields of management to find if it is possible to merge the Six Sigma/Lean Manufacturing initiative with additional concepts. This paper has shown that for example Total Productive Maintenance seems a likely candidate.

The case from a Scandinavian manufacturing company demonstrated that very few changes are needed in a Six Sigma programme in order to include also Lean Manufacturing principles and tools. The most significant changes can be found in the changes to the content of some of the courses in the Six Sigma training scheme. There should hence be very little practical hindrance for companies wanting to merge Six Sigma and Lean Manufacturing.

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