Lean Six Sigma Strategy at Work: Ups, Downs and Lessons Learned From Implementation - A Literature Review

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ABSTRACT
Research work on Lean, Six Sigma and Lean Six Sigma has become increasingly present in the literature in the field of operations management and business excellence and has extended to other areas as the need for process improvement is more prominent. Whether it analyzes theoretical aspects regarding the development and the evolution of the two methodologies or of the most recent merge between the two, known as Lean Six Sigma strategy or simply Lean Sigma, or it presents results of studies undertaken in different industry or service sectors, the knowledge provided by the articles, books or studies currently available is vital to all researchers, specialists in the field and to all businesses. In this consideration we propose a detailed review of the most significant findings drawn from studies concerning the evaluation of the performance of Lean Six Sigma strategy as pure theory or as evidence from organizations performed in the time-frame 2003 to 2014 that seeks to underline the lessons learned from implementation and to question what is to be done in future researches.

KEYWORDS: Lean, Six Sigma, Lean Six Sigma strategy, implementation, process, continuous improvement

JEL CLASSIFICATION: *I19, M10, M11*

INTRODUCTION

Lean and Six Sigma approaches go hand in hand as if they were conceived to coexist from the very beginning. Both methods encompass a number of principles and tools designed to increase the efficiency of a process by reducing wasteful steps. The Lean process strategy is attributed to Taiichi Ohno and the Toyota Production System, where specific types of manufacturing "waste" consuming essential company resources (personnel, raw material or time) but not adding value to the overall process or to the customer are eliminated. Lean is a method oriented on the workflow inside processes that seeks to improve it in a continuous manner to efficiently produce a product or service that is perceived to be of high value to the end user. Six Sigma is a different method to reduce process variation, to control probability and improve process capability through the rigorous application of process metrics, statistical analysis tools, optimization and consistency assurance methods (Taghizadegan, 2006).

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Although at the beginning they were each introduced and developed to tackle specific business process discrepancies in specific contexts, being often regarded as rival initiatives since Lean was considered to pay no attention at all to variation, Six Sigma was seen as only focused on quality and as having nothing to do with flow and speed, research has proved that nowadays the implementation of the combination of the two philosophies is more effective and efficient in attaining long term objectives at operational and tactical level concerning the performance of business processes.

The manufacturing industry has developed and managed processes to maximize efficiency. Increased efficiency results in enhanced productivity, decreased personnel costs, reduced waste, and increased financial performance. Recently, the focus has shifted from efficiencies gained at the production level to efficiencies gained across the entire organization. Lean and Six Sigma are two methodologies that can be used both for the work unit as well as at organizational level (McDaniel & Lanham, 2011).

There were pro and con arguments all the time but this was mainly because no one thought to benefit from the complementarity of the two methodologies. They have major common principles that blend together in such a perfect way that all businesses need in their quest for operational excellence. George (2003) underlines the idea that Lean Six Sigma lets organizations work on all three aspects simultaneously because it blends Lean, with its primary focus on process speed and flow, and Six Sigma, with its primary focus on process quality.

Both Lean and Six Sigma methodologies are quality improvement tools that have their origin in the manufacturing sector. Each is designed to improve quality and efficiency of a given process. Lean focuses on reducing wasteful or non value-added steps in a process, and Six Sigma reduces process variation through the application of statistical methods. However, the successful application of Lean and Six Sigma (LSS) and other similar management tools is not limited to manufacturing, but has been applied in the customer and financial service industries and the government. Increasingly, Lean and Six Sigma are being used in the healthcare industry, the specific tools of LSS being applied to several aspects of healthcare, like finance, inventory management, information processing, outpatient clinics, and inpatient setting. Thus the span of utilization of Lean and Six Sigma tools and techniques is extremely wide.

In many quality improvement projects, these different tools are complementary, which has led to merging them into a single strategy, i.e., LSS strategy (DelliFraine et al., 2010). Although they were observed for quite many years now, the results of LSS as a strategy in organizations are yet to be discussed. The findings of Cima et al. (2011) show that LSS is a methodology that has been applied to improving process efficiency on a limited scale.

Furthermore we will present a summary of the most relevant findings revealed by studies, analyses and researches, focusing on the most recent evidences from the area of LSS implementation and on those fields where the incidence of research work is higher.

1. METHODOLOGY

We based our research method on a systematic review of the existent literature. A systematic literature review is a method that adopts a precise, transparent and explicit approach that includes a series of phases to ensure that an appropriate rigour and transparency is brought to

the literature review process (Garza-Reyes, 2015). We then used a structured content analysis approach to summarize all relevant pieces of information needed to determine the current state of the LSS strategy implementation in organizations and to reveal the most essential tools, methods and techniques used, as well as the advantages and disadvantages of the initiative. In order to find publications, articles, research work relevant to the aim of the review, we considered searches in numerous publishers' electronic databases including ProQuest, Sciencedirect, Emerald, Taylor & Francis, EBSCO and Google Academic. Thus we analyzed numerous publications using for the searches the keywords "Lean", "Six Sigma" and "Lean Six Sigma", eventually filtrating and focusing our attention on 103 articles that we considered more relevant for the scope of the review, published in the time frame 2003-2015, starting with 2003, the year in which a number of significantly relevant researches on the topic of interest were found and ending with the latest in press studies made available at the beginning of 2015.

2. FINDINGS

2.1 Descriptive data related to the findings

In Figures 1, 2 and 3 we made a brief description of the typology of the publications analyzed, of the distribution of the articles per year of publication and of the number of organizations present in the case studies considered, according to the field of activity.

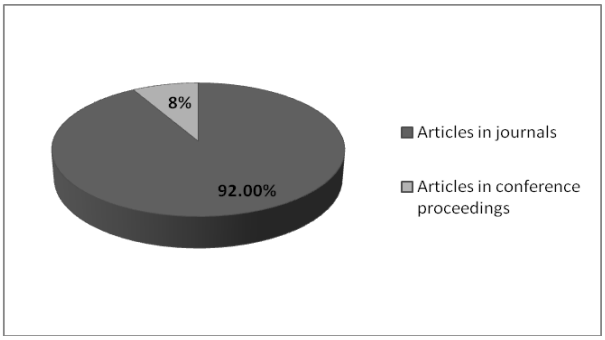

Figure 1. Type of publication of the researches on LSS strategy
Source: the authors

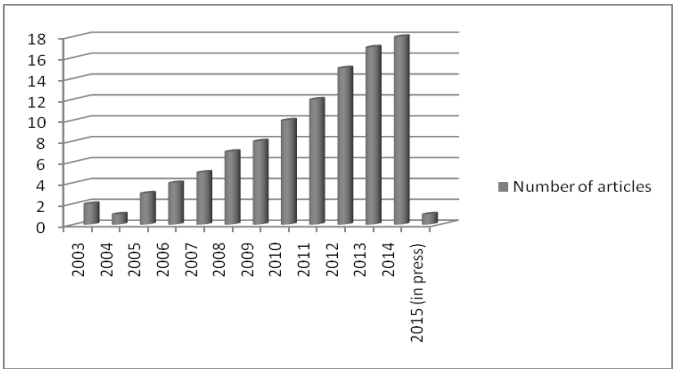

Figure 2. Number of articles per year of publication (2003-2015)
Source: the authors

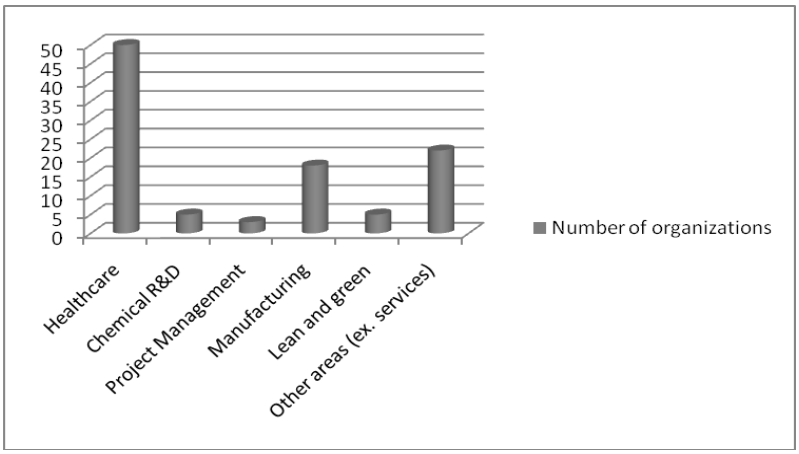

Figure 3. Number of organizations per field of activity
Source: the authors

2.2 LSS in healthcare

LSS has become increasingly popular in the field of healthcare in the past years. The majority of researches found were dedicated to LSS projects in various aspects of the healthcare domain. One of the most recent, very comprehensive and relevant research in this field was performed by Winters-Miner et al. (2014) in their book by which they try to address current problems in medical research and present the most essential LSS tools and methods recommended to be used in solving quality-related problems to deliver cost-effectiveness to medical care units. A series of examples and case studies are used to show how instruments like statistical process control, total quality management, Deming's principles, cost-benefit analysis, root-cause analysis, Ishikawa diagram, kaizen and many others work in hospitals and healthcare facilities.

We also considered as significant the following studies which were recently developed and since they are more facility-oriented, they provide evidence from particular organizations and systems thus making it easier to associate certain results to specific measures undertaken and to easily draw conclusions and best practices.

According to the study undertaken by Mueller et al. (2014), Lean and Six Sigma proved efficient in determining the variability in patient flow in order to make decisions regarding the improvement of processes. The study analyzed twenty-one women in the initial phase who experienced relatively short wait times for the first appointment, while the average wait time between appointments gradually increased. The patient flow through the cancer center was observed and inefficiencies were elucidated with the help of confirming the points of greatest process variability through value stream mapping and enlisting change management techniques to make adjustments on the spot.

The LSS methodology (DMAIC - define, measure, analyze, improve, and control) was also used in another research to improve discharge paperwork process (Neufeld et al., 2011). LSS tools like SIPOC (suppliers, inputs, process, outputs, and customers) and VOC (voice of the customer) were used in the same context. The various interventions that occurred during the implementation phase (education, policy change, and information technology

improvements) enabled the standardization of the improvement phase of LSS. Eight critical elements necessary in the discharge process were identified which were audited at baseline and after implementation of the interventions.

DMAIC and Kaizen methodologies were used to address process issues throughout the organization in a children's hospital where several improvement initiatives on determining discharge time, catheter-associated bloodstream infections, discharge teaching, handoff communication, ventilator-associated-pneumonia rates, medication-missing doses, and catheter-related-urinary tract infections were used (Bryant-Hampton et al., 2011). Employees felt ownership and encouragement during the quality improvement program working as part of interdisciplinary teams and applying LSS tools to help reorganize supplies and processes.

Other studies performed by Dickson (2013) and Lighter (2014) on a community hospital showed the utility of LSS in managing the quality and efficiency of processes by identifying and minimizing variability through defined sequence of phases (DMAIC phases). In the study of Dickson (2013) the issue was with the Total Joint Arthroplasty (TJA) Surgical Site Infections (SSI) which had been on the rise since mid 2010 and remained high despite all interventions performed. To solve the issues a LSS team with support from stakeholders was assigned. By the end of the analysis they had managed to identify the final root causes which were the gaps in horizontal infection prevention, the technique, and patient preoperative optimization and to find improvement measures.

The positive effect of the team approach in implementing LSS improvement was also demonstrated by Rossi et al. (2014) trying to analyze the problem of environmental healthcare disinfection. The results of the LSS efforts were the establishment of a standardized process for discharge room cleaning, a better definition of roles and responsibilities of departments to address major inefficiencies in the old process and the enhancement of communication between critical areas in the major process. All these results were attained by providing training to the owners of the activities from all clinical units with the use of multidisciplinary teams, by standardizing the critical processes, by visualizing the roles in those processes and by eventually mapping them.

Process mapping, leadership support, staff engagement and sharing performance metrics were also the keys to enhancing operating room efficiency in an academic medical center by using the DMAIC tool, as one of the studies performed by Cima et al. (2011) revealed. The initiative proposed by the institution demonstrated how the use of Lean and Six Sigma methodologies increased OR efficiency and financial performance across an entire operating suite and the performance gains obtained were substantial, sustainable, positive financially, and transferrable to other specialties. Smaller multidisciplinary teams were challenged to test surgical process improvement (SPI) by developing a value stream map of patient flow that detailed the event location, personnel, and information technology requirements, alternative pathways, key performance elements at each step, and bottlenecks.

2.3 LSS in chemical facilities

Another domain where researchers identified significant practices is the chemical industry and drug discovery and manufacturing. The results revealed are interesting especially from the perspective of linking LSS practices to innovation.

Managing with input metrics allows the workforce to understand the alignment between individual work and the tactical goals of management, as the findings of one of the researches performed in a plutonium facility of a laboratory show (Cournoyer et al., 2011). LSS business practices ensured the constant improvement of the efficiency, cost-effectiveness and formality of glove box operations through the use of control charts that signaled the absence or presence of systematic variations and the input metrics that were used to identify statistically significant variations (trends). Workers were informed what to look for and processes were established to methodically search for, document, and eliminate the causes of flawed defenses and error precursors, thus identifying and correcting weaknesses. Continuous improvement through feedback proved to be a primary means of identifying these weaknesses in work practices and organizational processes. LSS tools (process map, voice of the customer, cause and effect diagram, failure modes and effects analysis) were also used to identify corrective actions in an air purifying respirator process in a study performed by a similar team of researchers.

Other studies have suggested that continuous improvement, Lean, Six Sigma and process excellence are making a positive impact on drug discovery and development (Johnstone et al, 2011; Hammond and O'Donnell, 2008; Petrillo, 2007). Johnstone et al. (2011) speak about the potential traps in interpreting the three major elements of process thinking, which are the meaning of standardization, the role of variation and the choice of how to use liberated capacity, in making decisions based on them and in deploying them. They identified some key Lean elements to an innovative organization, such as: selecting the most important problems to address, the organization's attitude to problems, opportunities for horizontal thinking and multidisciplinary interaction, available capacity or resources to test and explore new approaches, confidence, motivation and engagement, reduction of frustration, and infrastructure.

In the pharmaceutical industry, the field of resource and development is highly competitive especially when we think of the advantages it brings to a company that wants to be the first to launch a new product, since this activity takes long time to proceed. In this regard, the reduction of cycle time is a major concern for process owners and managers, for the value-adding it brings to the product and the customer, to the health status of the population, but also to shareholders. At the same time, innovation in a context like this reaches its highest potential only when supported by robust, effective and quality-controlled processes.

Uncertainty in drug discovery is a major and costly issue. It can however be significantly diminished from earlier phases of product development by increasing speed to enable feedback earlier. The speed of delivering the product to the customer can also reduce waste through the information provided by the customer, that keeps the direction of research on a the right track, thus reducing wasteful unnecessary exploration, according to the study of Reinertsen and Shaeffer (2005). There is less evidence of reduced costs or improved overall efficiency in the field, but research focuses on demonstrating these benefits.

2.4 LSS in project-based organizations

The implementation of the Lean Six Sigma strategy seems to be a novelty for project-based organisations since there were very few articles found on this topic. Most studies referred to the use of one of the two above mentioned methodologies. We furthermore detail some of the most recent analyses in this area.

A study performed by Tenera and Pinto (2014) presented a Lean Six Sigma (LSS) project management process improvement model tested in a real enterprise environment which had a formal and established project management system based on Project Management Institute standards. The LSS proposed approach was a DMAIC cycle-based proposal with the implementation of which some classical Six Sigma tools have been tested and also adapted. Results shown that by continuously identifying and evaluating improvement opportunities in processes and decisions the proposed approach provided major advantages in reaching process improvement on project management practices, organizational results and process waste reduction.

Another study undertaken by Gillett et al (2010) reveals on how Six Sigma helped Caterpillar achieve strategic goals and execute strategy. The authors underline the fact that this kind of initiatives are most of the time introduced in a way that is particular to the organization, by taking the tools and the experience and translating them into a custom technique. Caterpillar managed to change for the better the way they managed the planning and the execution of their projects, using step-by-step metrics as milestones to ensure long-term effectiveness and profitability. A critical factor in this respect was the creation of a knowledge base through the training of those who were to become process owners and then little by little, the integration of all employees in the Six Sigma program. Caterpillar did not focus only on the alignment of its own processes but shared the knowledge with other small businesses and with its suppliers, by integrating 850 suppliers worldwide and thus creating 1000 supplier Black Belts that helped in running the projects.

2.5 LSS in manufacturing

Manufacturing is the field where Lean Six Sigma initiatives are to be observed in their most familiar environment. Toyota, Motorola, General Electric, Ford, Bombardier, DuPont, Sony are worldwide manufacturers that have gone down in history for the creation of the so called knowledge laboratories for the development of what we know today as the LSS strategy. However, although it is the homeland of LSS, we left this domain at the end of the list because lately the interest for LSS projects in manufacturing facilities has somehow reduced in intensity.

Krogstie and Martinsen (2013) used a case study approach to prove the importance of tolerance and variation management in achieving high value adding products with cost-effective processes. The authors discuss the link between tolerance engineering and the two manufacturing improvement philosophies, the try to deal with the gaps between the two and the limitations of Lean and Six Sigma on tolerance engineering. They propose the use of a conceptual model, Closed Loop Tolerance Engineering to help understand and coordinate the activities within the product development phase with the desired results.

Another interesting fact to observe was that research on LSS in the field of manufacturing has become increasingly focused on the implementation of this strategy in small and medium enterprises (SMEs). SMEs usually engage on markets that are already saturated or where competition is so high that no process errors and wastes are allowed to be noticed by the customers. They have fewer resources at their disposal and less time to learn and the need to change and adapt continuously is high.

The research performed by Antony et al (2008) in a pilot study on SMEs from UK reveals a very often problem incurred by SMEs that choose to implement LSS, the one of trying to implement best practices and most successful tools and wanting to see results over night, of not having an alignment between the initiative and the overall strategy, of not having sufficient resources and skills to invest in the initiative and in the end, of not knowing too much about this continuous and long journey to success. For this type of organizations we cannot speak of a fully implemented LSS strategy, but rather of a disparate use of instruments and techniques, the most required aspects of LSS being the critical success factors (CSFs) and the Six Sigma metrics for process control.

Another study of the CSFs of lean manufacturing in SMEs was undertaken by Dora et al (2013), the findings of which prove that the application of lean manufacturing practices in SMEs and especially in food processing SMEs is still at its infancy. The CSFs identified to be essential to these organizations are the skill of workforce, in-house expertise and organizational culture. The most relevant indicators of lean efforts to improve performance identified are stock/inventory reduction, productivity improvement, lead or cycle time reduction, quality improvement and improvement in on-time delivery. Most food processing SMEs seem to focus more on safety procedures and quality control rather than on continuous improvement tools and techniques.

The SMEs with manufacturing oriented processes in the Netherlands prove to benefit from linking to customer, vision and plan statement, communication and management involvement and participation, these being the most highly ranked CSFs according to the study by Timans et al (2012). The strongest impeding factors in the process of implementing LSS strategy reported by SMEs are internal resistance, the availability of resources, changing business focus and lack of leadership.

2.6 LSS at the crossroads with green initiatives

The last comments in the Findings section we decided to dedicate to the interrelationship of Lean philosophy and Six Sigma CSFs with the need to develop sustainable processes and the responsability to care for the environment. Although the topic is quite recent, there are increasingly more studies that deal with this concern.

The study performed by Chiarini (2014) on European motorcycle component manufacturers suggests that Lean Production tools can help reduce the environmental impacts of manufacturing companies. The tools that had greater impact on improving waste management and their demonstrated results were as follows: Value Stream Mapping - identify the environmental impacts of production processes, 5S – reduction of oil leakage, cellular manufacturing - decrease in electricity consumption, Total Productive Maintenance – reduction of several impacts of the machines (oil leakage, dusts and chemical fumes).

Another study (Kurdve et al, 2014) provides evidence from the Swedish industry, focusing on the integration of operations management, specifically production system models with environmental management. Findings reveal that there is a lack of sustainability metrics, a lack of responsibility and ownership of environmental management in relation to operations and major difficulties in adapting improvement methods to companies' own processes.

Finally, an empirical study performed as a review of the literature on Lean and green topics (Garza-Reyes, 2015) summarizes that the research on lean and green performance indicators has gone beyond the study and development of methods to determine the impact of these indicators on companies' performance. Researchers designed frameworks and models to identify the most appropriate key performance indicators and to adapt the necessary tools to evaluate the impact of processes on the environment, to connect and integrate lean and green principles and tools, to observe the interoperability within the supply chains.

CONCLUSIONS

Whether they treat theoretical aspects regarding the LSS strategy in organizations or practical findings and lessons learned from actual implementation, the articles in the literature are a relevant evidence database for researchers that are exploring the insights of the topic and an essential knowledge base for specialists and experts in the field that search for answers on what is, where is going and what can be improved in implementing the LSS strategy.

The articles analyzed revealed that the most explored field at the moment is that of healthcare. An increasing trend of expanding research can also be found in the field of waste management and green processes. The relationship between LSS and innovation is also an aspect that requires attention especially in times when we speak about continuous improvement and continuous change, development and progress. The implementation of LSS in SMEs is still to be questioned and explored therefore continuous research and observation in this area is recommended.

In the main sections of the article we presented the most relevant tools and techniques used, the CSFs and the impediments specific to those organizations that embarked on a LSS journey and the lessons learned and aspects to be considered for further development.

The research in the field is in a continuous process and findings should be disseminated and updated on a regular basis so as to have a critical and precise view on the subject.

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REFERENCES

Antony, J., Kumar, M. & Labib, A. (2008). Gearing Six Sigma into UK Manufacturing SMEs: Results from a Pilot Study. *The Journal of the Operational Research Society*, 59(4), pp. 482-493

Bryant-Hampton, L. & McElroy, J. (2011). Kids, Cars, and Karate: Quality Improvement Through Lean Six Sigma. *Journal of Pediatric Nursing: Nursing Care of Children and Families*, 26(4), 22.

Chiarini, A. (2014). Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers. *Journal of Cleaner Production*, 85, 226-233. http://dx.doi.org/10.1016/j.jclepro.2014.07.080

Cima, R., Brown, M., Hebl, J., Moore, R., Rogers, J., Kollengode et al. (2011). Use of Lean and Six Sigma Methodology to Improve Operating Room Efficiency in a High-Volume Tertiary-Care Academic Medical Center. Journal of American College of Surgeons, 213(1), 83-92.

Cournoyer, M. E., Renner, C., Lee, M. B., Kleinsteuber, J. F., Trujillo, C. M., Krieger, E. W., Kowalczyk, C. (2011). Lean Six Sigma tools, Part III: Input metrics for a Glovebox Glove Integrity Program. *Journal of Chemical Health & Safety*, January/February, 31-40.

DelliFraine, J., Langabeer, J. & Nembhard, I. (2010). Assessing the evidence of Six Sigma and Lean in the health care industry. Quality Management in Health Care, 19 (3), 211–225.

Dickson, A. (2013). Utilizing a Lean Six Sigma Approach to Reduce Total Joint Arthroplasty Surgical Site Infections in a Community Hospital. *American Journal of Infection Control*, 41, 131.

Dora, M., Kumar, M., Van Goubergen, D., Molnar, A. & Gellynck, X. (2013). Operational performance and critical success factors of lean manufacturing in European food processing SMEs. *Trends in Food Science & Technology*, 31, 156-164.

Garza-Reyes, J.A. (2015). Lean and green - a systematic review of the state of the art literature. *Journal of Cleaner Production*, in press, 1-12. http://dx.doi.org/10.1016/j.jclepro.2015.04.064

George, M. L. (2003). *Lean Six Sigma for Service: How to Use Lean Speed and Six Sigma Quality to Improve Services and Transactions*. New York: McGraw-Hill Companies, Inc.

Gillett, J., Fink, R. & Bevington, N. (2010). How Caterpillar Uses 6 SIGMA to Execute Strategy. *Strategic Finance*, April, 25-28.

Hammond, C. & O'Donnell, C. J. (2008). Lean six sigma – its application to drug discovery. *Drug Discovery World*, Spring, 11–18.

Johnstone, C., Pairaudeau, G. & Pettersson, J. A. (2011). Creativity, innovation and lean sigma: a controversial combination? *Drug Discovery Today*, 16(1/2), 50-57.

Kurdve, M., Zackrisson, M., Wiktorsson, M. & Harlin, U. (2014). Lean and green integration into production system models - experiences from Swedish industry. *Journal of Cleaner Production*, 85, 180-190. http://dx.doi.org/10.1016/j.jclepro.2014.04.013

Krogstie, L. & Martinsen, K. (2013). Beyond Lean and Six Sigma; Cross-Collaborative Improvement of Tolerances and Process Variations - A Case Study. *Procedia CIRP*, 7, 610 – 615. doi: 10.1016/j.procir.2013.06.041.

Lighter, D. E. (2014). The application of Lean Six Sigma to provide high-quality, reliable pediatric care. *International Journal of Pediatrics and Adolescent Medicine*, xx, 1-3. http://dx.doi.org/10.1016/j.ijpam.2014.09.009

McDaniel, R. & Lanham, H. J. (2011). Evidence as a tool for managerial action: a complex adaptive systems view. *Health Care Management Review*, 34(3), 216–218.

Mueller, J., Lothamer, H., Pelkofski, E., Novicoff, W. & Duska, L. (2014). Use of Lean and Six Sigma methodology to improve clinic efficiency in a high-volume tertiary care gynecologic oncology clinic. *Gynecologic Oncology*, 133, 141.

Neufeld, N. J., Cabahug, P., González Fernández, M., Mayer, S., Mehta, M., Powers, R. L. et al. (2011). Pre- and Postanalysis of a Lean Six Sigma Quality Improvement Project to Increase Discharge Paperwork Completeness to a Comprehensive Integrated Inpatient Rehabilitation Program. *PM&R*, 3(10S1), 317.

Petrillo, E. W. (2007). Lean thinking for drug discovery – better productivity for pharma. *Drug Discovery World*, Spring 9–14.

Reinertsen, D. & Shaeffer, L. (2005). Making R&D lean. *Research-Technology Management*, 48(4), 51–57.

Rossi, E., Mann, D., Baldwin-Rodriguez, B. & Alvarez, H. (2014). A Lean Six Sigma Approach to Improving the Discharge Room Cleaning Process. *American Journal of Infection Control*, 41, 143.

Taghizadegan, Salman (2006). *The Essentials of Lean Six Sigma*. Burlington, MA: Butterworth-Heinemann.

Tenera, A., Pinto, L. C. (2014). A Lean Six Sigma (LSS) project management improvement model. *Procedia - Social and Behavioral Sciences*, 119, 912 – 920. doi: 10.1016/j.sbspro.2014.03.102

Timans, W., Antony, J., Ahaus, K. & Van Solingen, R. (2012). Implementation of Lean Six Sigma in small- and medium-sized manufacturing enterprises in the Netherlands. *The Journal of the Operational Research Society*, 63(3), pp. 339-353.

Winters-Miner, L., Bolding, P., Hilbe, J., Goldstein, M., Hill, T., Nisbet, R. et al. (2014). *Practical Predictive Analytics and Decisioning Systems for Medicine: Informatics Accuracy and Cost-Effectiveness for Healthcare Administration and Delivery Including Medical Research*. London: Academic Press.