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Application of Lean Six Sigma for quality Improvement in Healthcare: A Review

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Abstract

Lean and Six Sigma are quality improvement methodologies developed in the manufacturing industry and have been applied to healthcare settings since the 1990s. The health care sector uses a methodical and consistent approach for Quality Improvement (QI), with an adjustable set of procedures that can be applied to various outcomes across different groups of patients. This review paper evaluates the published literature in the context of application and usefulness of Lean and Six Sigma methodologies in different healthcare areas during the last decade. On the basis of literature review the most effective LSS methodology is found to be DMAIC method and the scope of its implementation is quite wide in the entire healthcare setup.

Keywords: Lean Six Sigma, Healthcare, Quality Improvement

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INTRODUCTION

Health care, like any other service operation, requires continuous and systematic innovation to remain cost-effective and efficient, and provide high-quality services.In today's scenario it is imperative for healthcare providers to be proactive in quality improvement (QI) activities to improve health outcomes. Lean and Six Sigma methodologies can improve quality by increasing workflow efficiency and decreasing variation.Over the last decade, the world has experienced an unprecedented growth in improvement initiatives, such as lean thinking (lean) and six sigma (SS). Many researchers have reported the successful implementation of either Lean or Six-Sigma. Lean and Six-Sigma promote independent improvements, each with their own unique characteristics. SS advocates reduction in variation as essential, on the other hand, Lean attempts to organize human activities tocreate maximum value. Using both the processes in combination has proved to deliver more results. LSS has emerged to be a better tool for healthcare system because it relies on collaborative team effort in healthcare to improve the process by decreasing variations and add value to it. (Hseng-Long Yeh, Lin, Su, & Wang, 2011)

In this paper, the history of Lean and Six Sigma is discussed, the relationship between the two is emphasized, and their effects are studied when applied in the healthcare service. Since the market of health care is showing unprecedented growth, it has become important for the hospital and healthcare setups to ensure high quality services to their patients so as to meet their expectations. Improvement in healthcare service quality leads to patient satisfaction which in turn helps the healthcare organization to achieve patient retention and loyalty. To attain this goal, a hospital must implement LSS (Lean Six-Sigma) methodology for continuous improvement in the service quality because LSS methodology can ensure quality improvement in the service procedures and thus success of healthcare sector. (Ahmed, Manaf, & Islam, 2013)

HISTORY OF LEAN AND SIX SIGMA

Lean

Lean Production is a concept which was developed by TaiichiOhno in early 1950s to reduce waste (muda) from the production processing. The basic Lean concepts are: elimination of waste through process standardization and collaborative approach of all employees in process improvement. Lean in healthcare is about finding out the critical to quality factors with respect to the patient and distinguishing between activities which add value to the service quality by catering to the desires of the patients and activities that do not add value. Such Non value added activities (NVA) are called waste and ought to be removed.

Six-Sigma

The concept of six-sigma was introduced and implemented by Motorola in 1987 to improve quality. It measures quality performance by defects per million opportunities (dpmo) in the manufacturing sector, while in services sector it measures quality performance by errors per million opportunities (epmo). To minimize the errors and move towards excellence, most of the corporate hospitals are today operating at Three Sigma or Four Sigma quality levels."Six-Sigma can reduce variability and waste, translating to fewer errors, improve customer satisfaction, and provide better processes, greater patient satisfaction rates, and happier

and more productive staff". (R. &Mallikarjun, 2011). Six Sigma methods apply the statistical methods to achieve uniformity and preciseness in the processes. Six-Sigma uses the Define, Measure, Analyze, Improve and Control processes.It also involves the training and certification of designated process specialists (e.g. green belts, black belts) within organization to help guide Six Sigma improvement efforts.

Lean and Six- sigma

The integration of Lean and Six Sigma can achieve better results than what either system Lean or SS could not achieve alone. The integrated approach works well than previous approaches because it integrates the human (such as leadership, customer focus, cultural change, etc.) and process aspects (process capability, process management, statistical thinking) for improvement. (Antony, 2011).The combination of Lean and Six Sigma is essential because, "Lean philosophy cannot bring a process under statistical control and Six Sigma alone cannot drastically improve process speed or reduce invested capital" (George, 2002). LSS methodology makes use of DMAIC cycle to ensure the basic groundwork for service-quality improvement (Su et al., 2006). LSS uses quality control tools from both methodologies, thereby, enhancing speed of the process while also increasing accuracy (Mader, 2008; Munro, 2009). LSS has proved to be quite successful in the manufacturing sector in last two decades but the application of LSS in the service sector and particularly healthcare sector has been limited (Patton, 2005; Antony and Kumar, 2012). The application of LSS in manufacturing sector has been substantiated by ample evidences; however, the application of LSS methodologies within healthcare sector, especially in India, has limited empirical evidence. (Gijo et al., 2013; Gijo and Antony, 2013). The combined approach points to the process-centered and statistically data-driven basis of both Lean and Six Sigma. The researchers who advocate this blended approach claim that organizations can benefit by focusing on eliminating waste and customer-centric quality characterized in Lean along with the statistical tools and strategies for variation reduction featured in Six Sigma. LSS has been primarily used in health care industry in the departments of information processing, outpatient clinics and inpatient settings.

Literature Review

The literature was searched for the last decade with search strings "Lean Six Sigma in healthcare sector". The search showed results for application of lean in hospital processes, application of six- sigma to improve a hospital process and articles showing implementation of lean six sigma in hospitals. From these search results, only the papers focusing on lean six sigma were taken for the literature review. And their findings are listed below.

(Honda, Bernardo, Gerolamo, & Davis, 2018)found that applying Six Sigma and LSS concepts help in improving process performance, by reducing waiting time of the patients and thereby increasing patient satisfaction. Simultaneously, these process improvement techniques also help reduce operating costs and inventories, which lead to significant savings for hospitals. They concluded that by adopting collaborative team approach, with Six Sigma training, LSS can be successfully implemented. The hurdles in implementation were generally related to political hierarchy in hospital and its infrastructure.

(Mancosu et al., 2018) implemented the LSSM (lean six sigma methodology) in Radiotherapy (RT) department and redesigned the 2D-2D breast repositioning matching procedure used in WBRT (Whole breast radio therapy) for the early detection and cure of breast cancer. Six-sigma was applied for retrospective analysis of the database and then lean methodology was adopted to improve the process.

(Montella et al., 2017) implemented the LSS methodology to reduce the incidence rate of HAIs (Hospital Associated Infections). The methodology helped in the identification of variables causing the risk of HAIs and applied corrective actions to improve the care process, thus reducing the number of infected patients. They concluded that LSS is a useful tool that ensures a considerablereduction in the number of HAIs in patients undergoing surgical interventions. The application of LSS tools in the general surgery departments resulted in the decrease in the number of hospitalization days and also reduction in the number of patients affected by HAIs. Thus LSS along with other tools like surveillance, epidemiological guidelines and training of healthcare personnel, could be applied to reduce infection risk and improve a plethora of healthcare processes.

The results of the study show that it is possible to adapt business management tools like lean and six-sigma to the healthcare environment for effective rationalization of available resources and improving processes.

(Chaurasia, Garg, &Agarwal, 2017) concluded that a single module of LSS project in healthcare of patients with bone and brain metastasis through chemotherapy brings the reduction of waiting time of patients, their satisfaction and overall cost saving in healthcare hospital. LSS project can provide better healthcare organizational benefits such as pleasant work culture and environment, effective communication, customer satisfaction, inventory and operational cost reduction, responsiveness, flexibility of process, continuous improvement, improved financial capability, quality improvement, waste reduction, employees satisfaction, productivity improvement, lot size reduction, lead time reduction, suppliers morale, problem solving, product life cycle and digital waste reduction.

(Tagge, Thirumoorthi, Lenart, Garberoglio, & Mitchell, 2017) demonstrated that application of Lean Six Sigma methodology which is a well-coordinated and collaborative approach toward process improvement, can markedly improve efficiency in the operating room of an academic children's hospital, as measured by improved Turnover and Turnaround Time of the operation theatre across all surgical services.

(Amaratunga&Dobranowski, 2016)indicated that benefits can be derived through the application of Lean and Six Sigma methodologies within the field of radiology. However, whether the costs and effort of applying these methodologies outweigh the benefits and whether these prove better than other traditional health care QI methodologies, like quality assurance, audit programs, and so on, were questioned upon. A framework was provided by this review to improve the quality of evidence.

(Agarwal et al., 2016) observed a drastic improvement in the selected performance metrics like turn-time, physician downtime, on-time patient arrival, on-time physician arrival, on-time start as well as sheath-pulls inside the Cath-Lab after implementation of lean six sigma and thus concluded an improvement in operational efficiency of Cath Lab after implementation of lean Six Sigma Process.

(Mason, Nicolay, &Darzi, 2015) indicated a role for Lean and Six Sigma QI methodologies within surgery,

with significant improvements demonstrated across a variety of outcomes within the pre-operative, operative and in-patient settings.

(Improta et al., 2015) examined the usefulness of LSS as a tool to improve the management of patients undergoing prosthetic hip replacement surgery. They suggested that LSS could help in developing a clinical pathway that improves quality and, at the same time, reduces costs. The author remarked that LSS is a tool that can actually guarantee the improvement of the effectiveness of process and efficiency of health care delivery and provides an impetus for establishing best practice within the organization. The paper talks about advantages of LSS for patients by reducing their length of stay and increasing satisfaction with regards to health service; and also for hospitals, by reducing the costs for each admission, optimizing the waiting lists, better planning the operating lists and increasing the annual activity of the department.

(Bhat,Gijo, &Jnanesh, 2014)used the LSS DMAIC (Define-Measure-Analyze-Control) approach and its application in improving the workflow and resource consumption of the registration process in the Health Information Department (HID) of a Medical College hospital in India and concluded that this methodology gives a systematic approach towards problem solving. Moreover it was suggested that awareness and training regarding the methodology must be provided before the start of the study to avoid problems at different stages.

(Blick, 2013) demonstrated that Lean process improvements and six sigma initiatives can effectively deliver lifesaving health care using evidence-based protocols that depend heavily on "on time, every time" laboratory services to the emergency department.

(Kuo, Borycki, Kushniruk, & Lee, 2011) proposed a healthcare Quality Improvement model called "Healthcare Lean Six Sigma System (HLS3)" that integrates Lean Production System and Six Sigma methodologies to improve health care quality. The Lean methodology with tools such as root cause analysis, value stream maps allows identification ofactivities that could be altered to reduce waste and enhance quality. The Six Sigma methodology with tools such as house of Quality helps identify and prioritize the critical causes of poor workflow that could be improved by technology. Thus, this new model fills the service gaps between health care providers and patients and balances the requirements of health care managers, providers, and patients by reaping the benefits of the Lean speed and Six Sigma high-quality principles.

(Cima et al., 2011)applied Lean and Six Sigma methodologies across an entire surgical suite to improve its efficiency. Across three of the surgical specialties including gynecology oncology, general thoracic and colorectal surgery, the process was redesign which resulted in marked improvements in scheduled starts and reduction in scheduling number of cases past 5 pm. Substantial gains were achieved in non-operative time and staff overtime, indicating that LSS methodologies like process mapping, leadership support, staff engagement, and sharing performance metrics increases OR efficiency and financial performance.

(Carboneau, Benge, Jaco, & Robinson, 2010) organized a lean six sigma team which adopted DMAIC methodology to increase hand hygiene compliance and reduced hospital acquired MRSA (methicillin-resistant Staphylococcus aureus) infection by 51%.

(Turkyilmaz, Abeidi, &Uysal, 2018) applied the principles of lean production on in the emergency

department and achieved the reduction in the length of stay (LOS) of patients, thereby increasing the satisfaction of patients and medical staff. They detected critical quality factors affecting LOS by using process improvement methodologies and tools coupled with lean principles.

METHODOLOGY ADOPTED BY RESEARCHERS

From the above literature review, it is found that the researchers have applied below mentioned methodologies for the implementation of LSS process improvement.

- DMAIC methodology (Bhat et al., 2014; Carboneau et al., 2010; Chaurasia et al., 2017; Hseng-Long Yeh et al., 2011; Mancosu et al., 2018; Montella et al., 2017; Niemeijer, Trip, KTB, JMM, & Wendt, 2010; R. &Mallikarjun, 2011; Tagge et al., 2017; Turkyilmaz, Abeidi, &Uysal, n.d.)
- Define Phase: In this phase, once the opportunity for improvement is seen, the objective and scope of the project isclearly defined. VOC (Voice of customer) is recorded to determine the needs of the customers. In fact, VOCs are the basis of CTQ (critical to quality) considerations. The supplier-input-process-output-customer (SIPOC) flow chart, the high-level process map of the project, is developed in all cases.
- Measure Phase: In this phase, the measurable indicators are identified keeping in mind the operation definition of CTQ. The internal processes affecting the problem are examined, and performance is measured. The process includes making a data collection plan, construction of current-state value stream map (VSM) and measuring the performance. (George, 2003).
- Analyze Phase: In this phase, the data collected is analyzed and the appropriate statistical tools are applied to conduct value stream analysis for identification and validation of root causes for variations that occur in the non-value-added steps. The steps for analysis are:
- Data analysis:
    - Statistical analysis: It is conducted on the data collected from the measure phase; variation of the process is further discussed.
    - Process analysis: The critical process is analyzed to discover problems in the process and to determine with-value or non-value-added steps for customers.
    - Root cause analysis:Statistical tools, such as the Fish bone diagram, Pareto diagram and brainstorming etc., are applied to identify the major causes of process defects which are then prioritized for removal from the process.

• **Improve Phase:** This phase proposes the elimination of the root causes of defects that have the most impact on CTQs in the process. The solutions are applied to construct a future-state VSM (Value stream map)

•**Control Phase:** The purpose of this phase is to ensure that solutions are long lasting and reproducible. The phase is needed to keep track of process performance after quality improvement and to control the critical variables relating to performance.

- HLS3 Model was implemented and suggested by (Kuo et al., 2011). According to him “This model

bridges the service gaps between health care providers who are value-oriented and patients who are quality-oriented. It caters to the requirements of health care managers and delivers quality to the patients. It takes advantage of the benefits of Lean speed/value-maximum philosophy as well as Six Sigma's high-quality/low-variation principle." The main activities of the HLS3 model were:

- Identify: Identify the QI goal by hearing VOC
- Analyze: Study and analyze the current status of targeted process.
- Action: Transform the VOC into countermeasures and implement them
- Follow-up: Develop follow-up plan and deploy the knowledge throughout the organization.
- (Agarwal et al., 2016) implemented the continuous quality improvement initiative to improve cath lab. They used basic principles of Lean Six Sigma philosophy for the workflow process improvement in Cath Lab. They were:
- Challenge: Understanding the challenge imposed by the workflow process inefficiencies
- Kaizen: A Japanese word meaning continuous improvement
- GenchiGenbutsu: A Japanese concept that suggests a complete analysis of primary or source data before making decisions towards making changes.
- Reduction Of waste: Identification of three kinds of waste. "Muda" refers to non- value adding redundant work. "Muri" refers to overburden and "Mura" refers to unevenness and non-uniformity.

(Turkyilmaz et al., n.d.)conducted a process improvement study in the emergency department using the lean methodology and found out that following steps are essential to remove wastes/defects from the system.

1. Identify Value "from the standpoint of the end customer".
2. Value Stream Mapping "identify all the steps in the value stream for each product family, eliminating whenever possible those steps that do not create value".
3. Create Flow "make the value-creating steps occur in tight sequence so the product will flow smoothly toward the customer".
4. Establish Pull System "let customers pull value from the next upstream activity". 5. Seek Perfection "begin the process again and continue it until a state of perfection is reached in which perfect value is created with no waste".

DISCUSSION

On review of the methodology, we found that in seventy percent of the papers taken for review, DMAIC method was used for the implementation of LSS in various departments. A list has been tabulated for easy reference.

S.No	Author	Year	Place of study	Area of application of LSS	Methodology adopted
1.	Mancosu, Pietro Nicolini, Giorgia Goretti, Giulia De Rose, Fiorenza Franceschini, Davide Ferrari, Chiara Reggiori, Giacomo Tomatis, Stefano Scorsetti, Marta	2018	Radiotherapy Department, Clinical and Research Hospital, Milan-Rozzano, Italy	To redesign the 2D-2D breast repositioning process (Lean) by the retrospective analysis of the database (Six Sigma)	**DMAIC** *Define:* Problem Statement identified detailing the critical to quality characteristics *Measure*: Currently performed process was quantified, establishing the reference baseline *Analyze*: Statistical Analysis using STATA software, Fishbone diagram *Improve*: Reduction of errors in the matching process by the Poka-Yoke implementation. *Control:* Implementing control systems as statistical process control, visual workplaces, Kaizen.
2.	Montella, Emma Di Cicco, Maria Vincenza Ferraro, Anna Centobelli, Piera Raiola, Eliana Triassi, Maria Improta, Giovanni	2017	University Hospital, Naples, Italy	To reduce the incidence of health Associated Infections (HAIs)	**DMAIC** *Define:* SIPOC, Gnatt Chart and Focus group to identify CTQs *Measure*: Data collection *Analyze*: Control charts, histograms, Statistical tests(Chi-square and Fischer test), Scatter plot *Improve*: Weighted variable analysis *Control:* Monitoring using process indicators
3.	Chaurasia, Basant Garg, Dixit Agarwal, Ashish	2017	Chemotherapy oncology department in a cancer hospital in Delhi	Reduction in waiting time of patients with bone and brain metastasis undergoing chemotherapy, increased patient satisfaction and overall cost reduction in hospital	**DMAIC** *Define*: Project charter, SIPOC, VOC translation matrix, tree diagram *Measure*: Data collection plan, check-sheets, value stream mapping *Analyze*: Check sheet, data analysis, cause and effect diagram, value stream mapping *Improve*: Weighted criteria matrix, PDCA

					Control: Control Plan, Documentation
4.	Tagge, Edward P. Thirumoorthi, Arul S. Lenart, John Garberoglio, Carlos Mitchell, Kenneth W.	2017	Academic Children's Hospital California, USA	Improvement in efficiency of the operating room	**DMAIC** *Define*: Project Charter, process Map, SIPOC *Measure*: Data collection from EMR, Histogram *Analyze*: fishbone diagrams, scatter plots, box and whisker plots, histograms, Pareto charts *Improve*: Identified nine process changes to improve. *Control:* Turnover time and turnaround time were kept as measures to check impact of change.
5.	Improta, Giovanni Balato, Giovanni Romano, Maria Carpentieri, Francesco Bifulco, Paolo Alessandro Russo, Mario Rosa, Donato Triassi, Maria Cesarelli, Mario	2015	Complex Operative Unit, Orthopedics & Traumatology, University Hospital, Southern Italy	Applying Lean Six Sigma for the management of patients undergoing prosthetic hip replacement surgery	**DMAIC** *Define*: Project charter, CTQ Identification, SIPOC *Measure*: Current process performance was measured, Collection of retrospective data, histograms, run charts *Analyze*: VSM prepared and NVA identified, Fishbone diagram, brainstorming and statistical analysis. *Improve*: Standardization of discharge process, process plan with lean vision. *Control:* Comparative statistical analysis, periodic review meetings, internal audit checklist, Run chart is periodically updated.
6.	Bhat, Shreeranga Gijo, E. V. Jnanesh, N. A.	2014	Hospital Information Department of an Indian Hospital.	Apply LSS in OP-HID (Out-patient-Hospital Information department) to reduce waiting time of patients.	**DMAIC** *Define*: Project charter, CTQ Identification, SIPOC *Measure*: Data Collection plan to determine process sigma level. *Analyze*: VSM prepared and NVA identified, Fishbone diagram, GEMBA method of validation. *Improve*: Design and implementation of solutions in the process to improve performance of CTQ. *Control:* Poka-Yoke, 5S Audit Sheet, Standardized procedure of registration, X-bar R control chart, software

					program for display of availability of doctors.
7.	R., Rohini Mallikarjun, J.	2011	Multispecialty Hospital, Bangalore, India	Improving the quality of operation theater	**DMAIC** *Define:* Project charter, High level process map, Measurable customer requirements *Measure*: Data collection Plan (DCP) *Analyze*: Data Analysis, Process Analysis, Fish bone diagram *Improve*: Brain storming session *Control:* Monitoring using supervisor control
8.	Hseng-Long Yeh Lin, Chin-Sen Su, Chao-Ton Wang, Pa-Chun	2011	778 bedded, private hospital in Taipei city, Taiwan	To reduce the D2B (Door to balloon) time for STEMI (ST elevation myocardial infection) patients in cardiology department	**DMAIC** *Define*: Project charter, Customer requirements, High level flow chart (SIPOC) *Measure*: Recording of time from the entry of patient to the balloon inflation, statistical analysis *Analyze*: Check sheet, data analysis, cause and effect diagram, value stream mapping *Improve*: Identify and implement solutions *Control*: Monitoring
9.	Niemeijer, GC Trip, A KTB, Ahaus JMM, Ronald Wendt, KW	2010	University Medical Center Groningen, Netherlands	Improvement in discharge procedure of the patients by reducing length of stay at hospital	**DMAIC** *Define*: SIPOC *Measure*: Translation of problem into measurable indicators called CTQs *Analyze*: Checking the appropriateness of Length of Stay (LOS) using Appropriateness Evaluation Protocol (D-AEP). *Improve*: The result of analyze phase was communicated to care providers after 2 month for improvement. *Control*: As a process control plan, a dashboard was created to make admissions and average LOS transparent and visible.

10.	Carboneau, Clark Benge, Eddie Jaco, Mary T. Robinson, Mary	2010	Presbyterian Healthcare Services (PHS) in Albuquerque, New Mexico	Lean Six Sigma Improvement team was chartered to increase hand hygiene compliance to 90%	**DMAIC** *Define*: SIPOC, Obtaining VOC by asking questions from providers, staff, patients etc. and converting them to CTQs *Measure*: a) understanding current performance level by detailed process flow map. b) Narrow down the list of potential root causes through Pareto Chart, Cause and Effect diagram and FMEA. *Analyze*: Verify the key root causes by collecting and analyzing specific data. Statistical analysis on staff education, hand hygiene culture and environmental surveillance. Use of one proportion test. *Improve*: Identify and implement solutions *Control*: Monthly Control Plan, Safety coach program.

CONCLUSION

This review paper confirms that LSS DMAIC methodology can ensure the success of the healthcare center through the continuous quality improvement in the service procedures. It helps the healthcare setup to establish a continuous improvement process in the healthcare service, thus ensuring quality and accuracy in results in timely manner. Provision of accurate results to the health-care providers enables them to diagnose and treat patients with a higher quality of care. The LSS methodologies can be executed in the following healthcare processes:

- increasing capacity in X-ray rooms;
- increasing surgical capacity;
- increasing productivity of healthcare personnel;
- Reducing the patient wait time
- Reducing the time of patient stay in ICU
- increasing accuracy of laboratory results; and
- increasing accuracy of billing processes, thereby reducing the number of billing errors.

LSS DMAIC method has wide applications and the steps to be followed can be extrapolated to various processes in various departments. The only barrier to its implementation seems to be that a set standard procedure cannot be devised due to the differences in processes across various departments and the challenges in managing the healthcare providers.

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