Performance Enhancement and Continuous Improvement in Healthcare: How Lean Six Sigma "Hits the Target"

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Abstract

This article explores the potentials of Lean Six Sigma (LSS) in Healthcare, presenting and discussing one case study developed adopting an action research approach. The article aims are threefold: a) evaluate performance improvement in the Healthcare institution under analysis; b) discuss the potentialities of LSS tools and principles when applied to Healthcare organizations; c) highlight the factors enabling a LSS intervention in a Healthcare setting. The expected results are multifaceted. First, improvements are anticipated to relate to the performance of professionals in terms of increased efficiency, as well as to cost savings and time reductions in providing care services. Second, the case study underlines that Healthcare institutions would greatly benefit from a combined use of Lean and Six Sigma. Third, the case study is presented as a successful implementation of LSS due to a few key factors: institutional leadership, communication, personnel training, and employee empowerment.

Keywords: Lean Six Sigma, Healthcare, DMAIC, performance improvement, quality improvement.

1. Introduction

The number and variety of operation management and operation research (OM/OR) applications and projects in Healthcare (HC) have considerably increased in the last few years (Brailsford and Vissers, 2011). The underlying factors are numerous, ranging from demographic trends (in particular, ageing), to rising costs, and the necessity to face a variety of customer demands. In particular, customers (mainly patients and their families) are no longer willing to accept poor quality services, and face long waiting times, on the contrary requiring quick answers, and high value interventions. In this scenario, Lean principles and tools have been used in Healthcare to attack principal causes of inefficiency (i.e., waste), increase the quality of the services being provided and reduce costs (Robinson et al., 2012; Radnor and Osborne, 2013). The literature reveals the potentials of Lean tools in Healthcare all over the world (de Souza, 2009), and clearly highlights its benefits, mostly in terms of increased added value and quality (Kumaraswamy, 2012), and reductions in waiting time, errors and costs (Kimsey, 2010).

Moreover Lean is said to induce a variety of intangible positive impacts, such as increased customer satisfaction, employee motivation and commitment (Holden, 2011; Albliwi et al., 2015), and even enhanced safety (Young, 2014). However, the literature also reveals the presence of a number of barriers to Lean intervention (de Souza and Pidd, 2011; Chiarini and Bracci, 2013), specifically suggesting to combine its fundamental principles with other OM/OR tools and techniques, as it happens for Lean Six Sigma (LSS) which is the focus of this article.

It is noteworthy that LSS is increasingly implemented in many business sectors ranging from manufacturing to services to commercial finance organizations (Fraser and Fraser, 2011) and both in private and public organizations (e.g., George, 2003; Radnor et al., 2006; Furterer, 2009; Pepper and Spedding, 2010). As mentioned, this article specifically focuses on the implementation of LSS in Healthcare starting from an underlying motivation: as Proudlove et al. (2008: 28) claim "while it is widely acknowledged that operations management approaches are applicable in healthcare, and all the principal approaches have been tried, implementation has been little researched".

In this light, the article presents and discusses the key features and results of a LSS project developed in an Italian hospital. The case study is developed adopting an action research approach. The article aims are threefold: first, evaluate performance improvement in the organization under analysis; second, provide some considerations on the potentialities of LSS tools and principles when applied to Healthcare organizations; third, highlight the factors enabling a LSS intervention in this specific Healthcare setting.

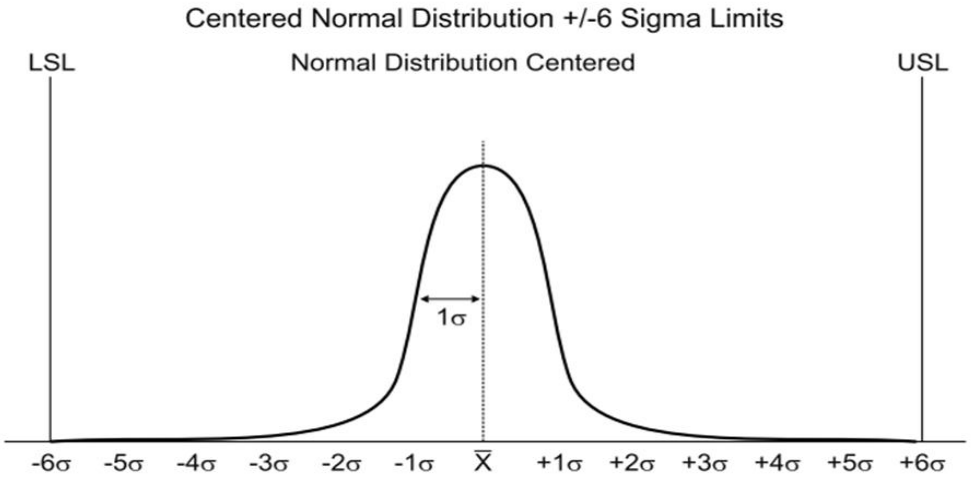
The article is subsequently structured as follows: the next sections briefly present the key features of Six Sigma, Lean, and Lean Six Sigma. The case study is presented afterwards. Discussion and final remarks conclude the article.

2. Six Sigma: A General Overview

Originally developed by Motorola in the 80s, Six Sigma subsequently gradually spread and was implemented by well-known companies such as Allied Signal and General Electric (Slater, 1993; Slater, 1994; Neuman and Cavanagh, 2000) and in a variety of SMEs all over the world (Antony et al., 2008; Timans et al., 2012). More recently, Six Sigma gained attention beyond the manufacturing world being adopted in other business sectors, such as service organizations (George, 2003; Taylor, 2009; Furterer, 2009; Pepper and Spedding, 2010), public administrations and healthcare institutions (de Koning et al., 2006; Proudlove et al., 2008; Kimsey, 2010).

The term "Six Sigma" refers to a statistical measure arising from the relationship between the variation in a process or operation and the customer requirements associated with that process.

Figure 1: Normal distribution and +/- sigma intervals



Source: George (2003: 25).

In the normal distribution displayed above, the largest concentration of values is around the mean and tails off symmetrically. The distance between the mean and the inflection point is the *standard deviation* and is commonly identified in statistics with the Greek letter "*Sigma*" (σ). The standard deviation represents the variability of the process, and the Sigma concept is widely used to understand the degree of such variability: in detail, 68% of the data falls within one standard deviation above or below the mean, 95% within 2σ, and 99% within 3σ.

Six Sigma numbers represent how the distribution of actual outputs compares to the range of acceptable values (customer specifications – lower specification limit, or LSL, and upper specification limit, or USL). The more of the distribution that fits within the specifications, the higher the sigma level. A defect is any value that falls outside customer specifications. To compare different processes, it is usual to standardize by reporting a defect rate (defects per million opportunities) rather than raw counts (Pyzdek and Keller, 2014), as shown below.

Table 1: Sigma levels

Sigma Level	*Defects per million opportunities*	*Yield*
6	3.4	99.9997%
5	233	99.977%
4	6,210	99.379%
3	66,807	93.32%
2	308,537	69.2%
1	690,000	31%

Source: George (2003: 25).

Thus, focusing on an interval of 6σ is equal to seek perfection and continuous improvement being the margin of error reduced to a very small number: just 3.4 defects per million products, despite expected fluctuations. In sum, Six Sigma offers "a structured and systematic approach to process improvement" (Pepper and Spedding, 2010: 142) and is considered a "product improvement or (re-) design approach" (Proudlove et al., 2008: 27). However, whereas Six Sigma focuses on variability reduction, it cannot be considered a general *strategy* for improvement and clearly does not directly address the issue of wasteful activities (Hopp and Spearman, 2004). These are the reasons why the literature is increasingly suggesting combining Six Sigma with Lean principles.

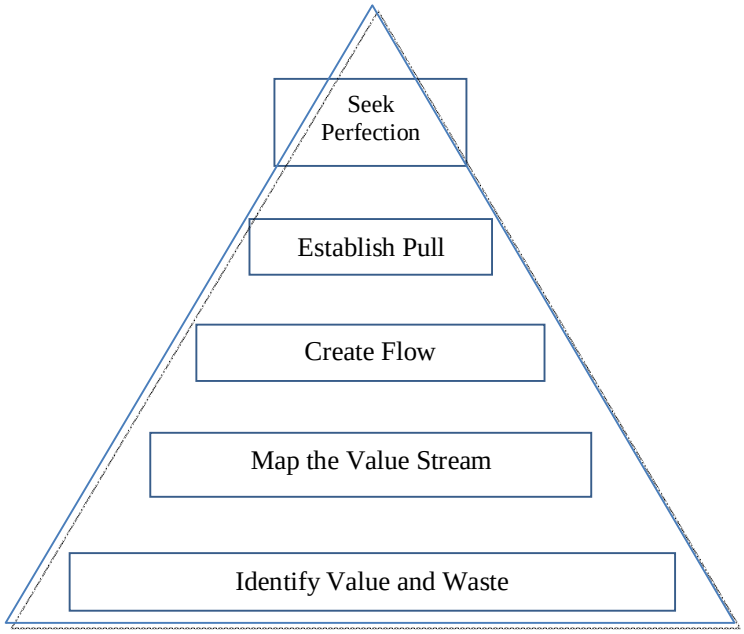
3. The key principles of Lean

Lean is one of the several innovations introduced by Japanese manufacturers in the 80s as a consequence of the scarcity of resources and increased domestic competition affecting the Japanese automobile market (Hines et al., 2004). Most of these tools were meant to reduce costs and waste and increase the value created along specific processes. In detail, Lean originated within the Toyota Motor Company (see Krafcik, 1988; Ohno,1988) as an alternative way to the traditional method of mass production and batching principles for optimal efficiency, quality, speed, and cost (Holweg, 2007; Radnor and Osborne, 2013). Lean did not acquire great relevance for several years and the interest by Western authors and manufacturers increased only after the publication of the book titled "The machine that changed the world" by Womack, Jones and Roos (1990).

The fundamental principle of Lean is that value creation is pursued through the elimination of wasteful activities, labelled with the Japanese term *muda*, being the most common categories of muda the so-called "Toyota seven-wastes" as identified by Ohno (1988) in describing the Toyota Production System (TPS): overproduction; waiting; transporting; over-processing; unnecessary inventory; unnecessary/excess motion; defects. The method also aims at designing-out overburden (*muri*) and inconsistency (*mura*), subsequently reducing costs(Hines et al., 2004) and increasing profitability in the long-term (Meade et al., 2010) and customer satisfaction through better customer service/quality (Radnor and Johnston, 2013).

To do so, Lean operates through five fundamental principles, summarized in Figure 2:

Figure 2: Fundamental principles of Lean



Source: Adapted from Ohno (1988), Womack et al. (1990), Womack and Jones (1996).

Only a small part of the total effort and activities carried out by an organization actually adds *value* for the end customer. Subsequently, it is necessary to identify who is the end customer, which activities add value (VA) from the end customer's perspective and which are non-value activities (NVA), i.e. *waste*.

The second step implies to identify and *map* (using a Value Stream Map) all the activities across the organization that are involved and play a role in jointly delivering the product or service. Those activities that do not create value should be eliminated.

Subsequently, the approach requires generating the flow of activities to be performed in sequence so to *flow* to the customers without waste, interruptions or waiting. The whole process is regulated upon pull logic: as soon as a flow is introduced, the customer pulls value from the next upstream activity, i.e. the system is demand-driven.
The system is overall organized to pursue *perfection* and continuous improvement.

In brief, Lean strives to eliminate waste to increase performance and value added in reference to a specific process or value stream. We stress again that value creation is valuated adopting the customer point of view and should not reflect providers' interests; therefore, waste is by definition anything that "does not add value to the customer" (Holden, 2011: 265).

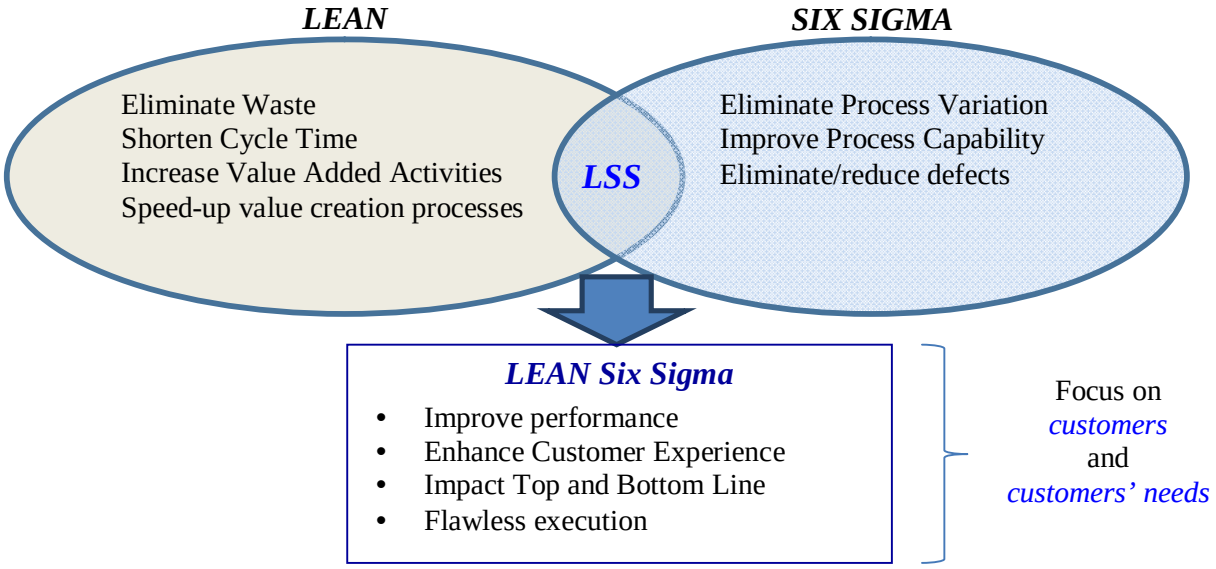
As aforementioned, Lean was first implemented in US auto manufacturing, and subsequently in many other production systems, and also in the service industry (Arfmann and Barbe, 2014). More recently, Lean spread in the public sector (Radnor and Johnston, 2013; Radnor and Osborne, 2013) and is currently applied in combination with other methodologies and approaches as in the case of Lean Six Sigma in the Healthcare sector.

In this specific regard, however, no clear consensus is found on how the integration between Lean and Six Sigma is to be done, and which are the steps to subsequently develop a LSS project. As claimed by Proudlove et al. (2008: 28): "Lean and Six Sigma (…) are increasingly being integrated in practice (…) although there is no consensus on how this should be done. (…) The distinctions between Lean and Six Sigma in practice are not as clear cut as the academic literature might suggest".

4. Integrating Lean and Six Sigma in Healthcare: overview and literature review

An increasing number of articles and books (e.g., George, 2003; George and Rowlands, 2003; George et al., 2005; Proudlove et al., 2008; Chiarini and Bracci, 2013; Albliwi et al., 2015) claims that a fruitful integration between Lean and Six Sigma principles and operational tools would allow to simultaneously exploit their main strengths, at the same time not generating any contradiction for their respective core objectives. In detail, Lean and Six Sigma can be successfully teamed since they provide complementary benefits:

Figure 3: Integrating Lean and Six Sigma



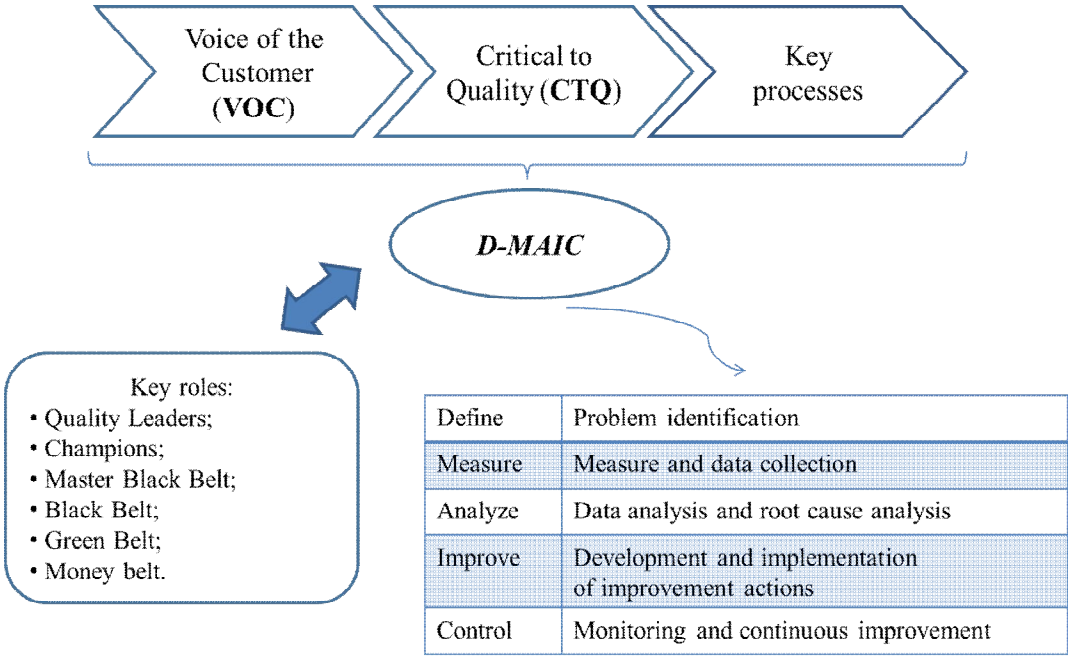
As portrayed in Figure 3, whereas Six Sigma is mainly focused on process quality and heavily relies on statistical tools to bring processes under control (Pyzdek and Keller, 2014), Lean offers the *speed tools* (Tolga Taner et al., 2007) needed to increase quickly efficiency and eliminate fluctuations, at the same time providing a complete sustaining infrastructure based on a core set of key management principles looking at the customer as the main reference point for value creation. In this context, LSS represents an overlapping area, and is able to exploit both Lean management and Six Sigma principles and tools. Subsequently, LSS is suitable to support strategic initiatives aimed at improving, optimizing, and continuously managing a variety of processes.

To be operationalized, LSS requires organizations to go through an implementation process articulated into a few steps.

1) The organization identifies the *customers* of the process/service, alongside their needs either expressed or unexpressed (the *Voice of the Customer* - VOC).
2) The organization identifies the *Critical to Quality* (CTQ), that is to say the characteristics that are crucial in view of the customer to define the quality of the product/service under analysis.
3) Then, it is necessary to focus on the activities and processes that are fundamental for the CTQs.
4) Subsequently, senior managers identify the strategic objectives to focus on, and to pursue through a series of improvement projects ("deployment") specifically designed to reduce the variability of the CTQs.
5) Last, few Six Sigma micro-projects are developed and implemented to pursue continuous improvement goals in reference to each critical process. Methodologies used primarily to this end include (Proudlove et al., 2008: 27) Design for Six-Sigma (DFSS - see Yang and El-Haik, 2003; Brue and Launsby, 2003) and DMAIC (Define, Measure, Analyze, Improve and Control), the latter described subsequently.

Acronym of the terms Define, Measure, Analyze, Improve and Control, DMAIC is a rigorous and well-known problem solving method which is frequently used in the analysis of problematic issues, for the identification of their root causes and the development, implementation and monitoring of improvement actions. To this aim, LSS builds on previous research on process improvement - in particular, on Deming's Plan-Do-Check-Act cycle (PDCA) - at the same time providing guidance to the user both with a core set of fundamental methodological principles (the basic Lean principles) and a structured methodology for operationalizing it (DMAIC).
All the previous considerations are summarized in Figure 4.

Figure 4: LSS and DMAIC



Taking into consideration the Healthcare sector, it is noteworthy that the academic literature reports, presents and discusses the design and development of many LSS projects across various countries and hospital departments (e.g., de Koning et al., 2006; Proudlove et al., 2008; Kimsey, 2010), alongside more focused Six Sigma projects (e.g., Sehwail and DeYong, 2003; Young et al., 2004; Tolga Taner et al., 2007; Feng and Manuel, 2008; Liberatore, 2013), Lean implementations (e.g., de Souza, 2009; Kimsey, 2010; Southard and Kumar, 2012) and interventions based on other OR tools (e.g., Proudlove et al., 2007; Feng and Antony, 2010). Moreover, a number of research articles and case studies reported data and information on very specific and focused issues for which LSS was chosen (e.g., Fairbanks, 2007; Cima et al., 2011).

Less attention was instead devoted to the implementation of those initiatives, the methods adopted to do so (Mostafa et al., 2013) and the factors enabling such implementations (Pakdil and Leonard, 2014). Furthermore, it is noteworthy that Lean and Six Sigma have undergone a process of parallel development in recent years (de Koning et al., 2006), this calling for more research on their actual combined implementation, especially through the presentation of case studies and action research projects (Pepper and Spedding, 2010; Radnor and Osborne, 2013). Last, calls for more evidence-based applications of Lean and LSS in HC settings arise due to the likely presence of a number of implementation barriers that may exist in those settings that make interesting to discuss the features of successful LSS projects (Radnor et al., 2006; de Souza and Pidd, 2011). In brief, with reference to LSS and HC it is not entirely clear how (Chiarini and Bracci, 2013) - or even *if* - Lean and Six Sigma can co-exist, as we aim to discuss with the case study presented afterwards.

5. The case Study

5.1. Research methodology

The article presents a *case study* (Yin, 1994; Voss et al., 2002) developed with an *Action research* perspective (Lewin, 1946; Hart and Bond, 1995). In detail, this section reports on the implementation of a LSS project in the Ward of *Respiratory disease and lung transplantation* in a hospital of large size. On a yearly basis, the Hospital treats around 50,000 inpatients in its ER Department, admits over 35,000 patients in its wards, provides over 3,200,000 medical care services, and manages around 800 beds. It is noteworthy that the Hospital is characterized by strong extra-territorial attractiveness since 40% of the patients are from outside the Region. The LSS project we present is to be regarded as the first *pilot* intervention run by the Hospital, being actually followed by a large campaign of other LSS projects given this first successful implementation.

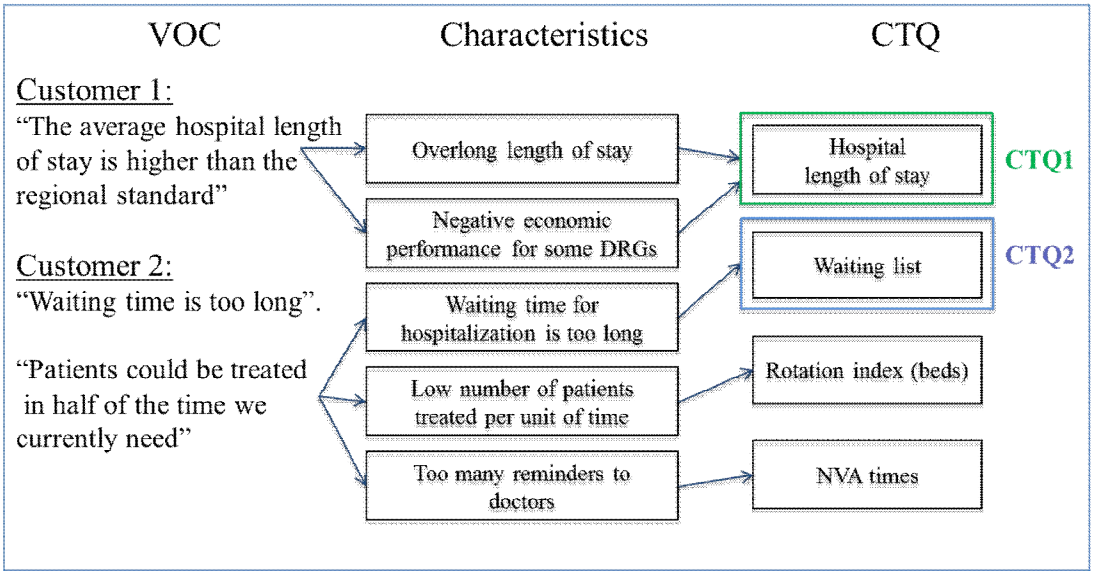
The project was developed over a 6-month period. Historical data were collected and analyzed prior to the beginning of the LSS intervention. Further data and information were collected and analyzed cooperating with the Team in charge of the project and conducting several interviews with senior figures and professionals working in the Hospital during a few months after the conclusion of the project. The main goal pursued with the LSS project was to increase physicians' productivity, reduce operational costs and deliver services of increased quality. More specifically, the LSS project was aimed at reducing the average length of stay for inpatients bringing this measure in line with Regional targets. DMAIC was selected to operationalize LSS, as subsequently discussed.

5.2. DMAIC in action

Define

The first phase of DMAIC (as portrayed in figure 5) focuses on problem identification. To do so, a Quality Team in charge of the project was appointed with the aim to identify CTQs, define the strategic goals to pursue and organize all the activities to be carried out during the LSS intervention. The Team included the Chief Medical Officer (Customer 1) as main Sponsor for CTQ1 (length of stay), and the Ward Director (Customer 2) as main Sponsor for CTQ2 (waiting list). Several meetings between the Lean Green belt and the main Sponsors were conducted to identify the VOC.

Figure 5: VOC and CTQs



The CTQs identified in this phase can be described as follows.

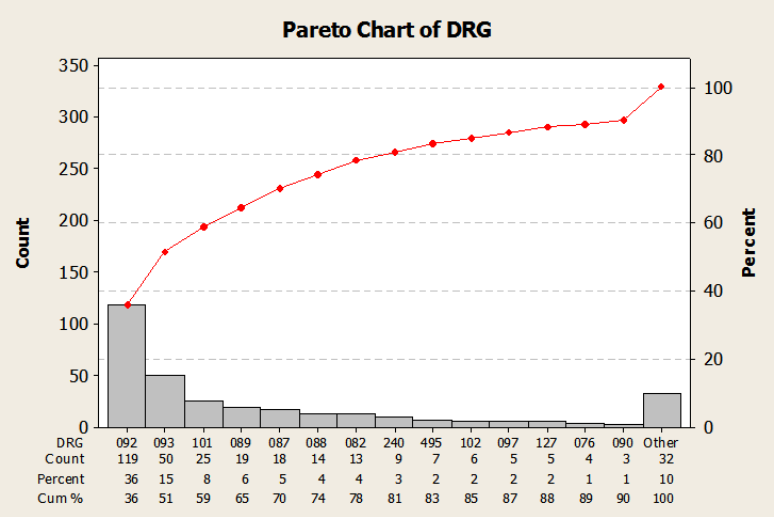
Table 2: CTQs' characteristics

CTQ	*Definition*	*LSL*	*USL*	*Target*	*Defect*
1. Length of stay	Length of stay of patients in the Ward expressed in fractions of a day. Date and time of exit – Date and time of entry.	3	7	Avg. Length of stay = 6 days	Length of stay equal or more than 7 days
2.Waiting time for hospitalization	Waiting time (no. of days) for hospitalization in the Ward	N/A	N/A	Reduction of waiting time and balance among DRGs	To be defined

The following step of the Define phase consisted in identifying the *Ring* and subsequently the "in scope" patients, i.e. those of interest for the project. As shown in Table 2 and Figure 6, the focus is placed on DRGs (Diagnosis-Related Groups), used to "group together treatments that are clinically similar, consume similar quantities of resources and are likely to be similar in cost" (DoH, 1998: 4). The calculations revealed a bad situation for a few DRGs and the cost of hospitalization equal to 418.27 €/day.

More specifically, the analysis allowed identifying patients DRG 093 "*Interstitial Lung Disease without CC*" (+ 092) as "in scope" while all other typologies were classified as "out of scope" (i.e., not the focus for the project), as also demonstrated by the Pareto chart shown in Figure 6. It is noteworthy to remind that a Pareto chart is a graph that uses both bars and lines: individual values characterizing the phenomenon under analysis are represented in descending order by bars, and the cumulative sum is displayed by the line.

Figure 6: Pareto chart of DRGs

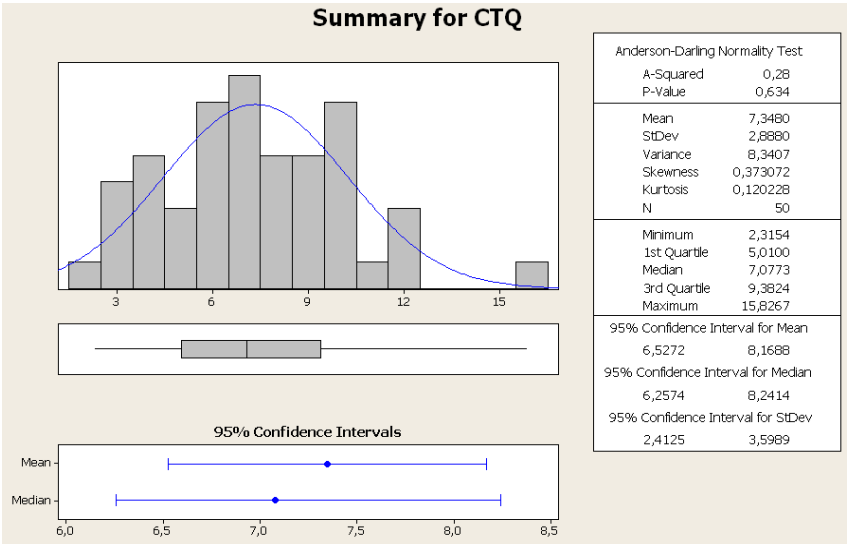


A short training course delivered by the Green belt to the Ward personnel and Quality Team followed this step of the project. The Define phase was concluded building a map of the process, exclusively for patients with DRG 093. It is to stress that we will primarily focus on CTQ1 presenting the next stages of DMAIC.

Measure

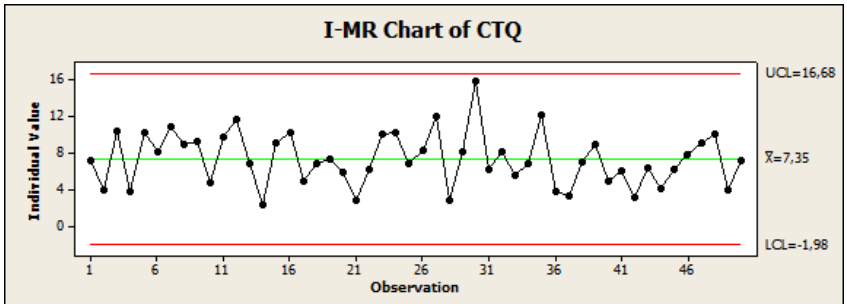
This phase started with a historical data collection, considering patients being discharged by the Ward during a period of 7 months previous to the project (50 cases in DRG 093 - 15% of the total). The data source was further validated through a Gage R&R for attributes by comparing the measurements collected with data from records of 20 patients discharged from the Ward. This analysis returned a 96%result, which validated the measuring system. Data showed a normal distribution for CTQ1 (p-value of 0.634 according to the Anderson Darling Normality Test) with very high variability (around 13 days, with a lower limit of 2.3 days and an upper limit of 15.8 days). Mean was equal to 7.348 days, median was 7.077 days and standard deviation was 2.888 days, as shown in Figure 7.

Figure 7: Summary for CTQ



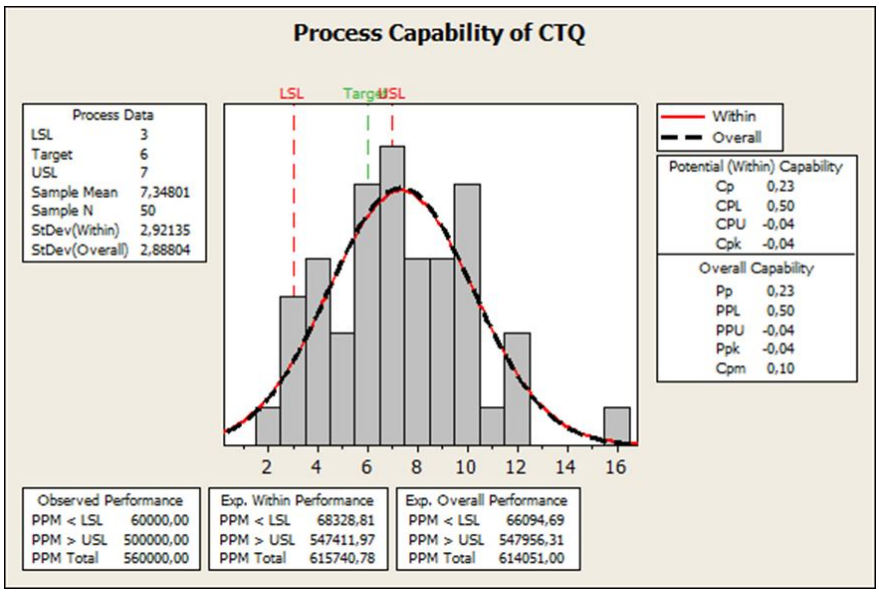
50% of the output was not compliant according to the definition of *defect* given for this CTQ. As already shown, LSL and USL were set respectively at 3 days and 7 days to comply with Regional standards. Overall, the process was considered under statistical control, although extremely variable (ranging between 2 and 16 days) with respect to customers' requirements.

Figure 8: Summary for CTQ



Process performance was equal to 38.59% (614.051 PPM), process capability was negative (-0.04) and process sigma was equal to 1.21, as also summarized in Figure 9.

Figure 9: Process capability of CTQ

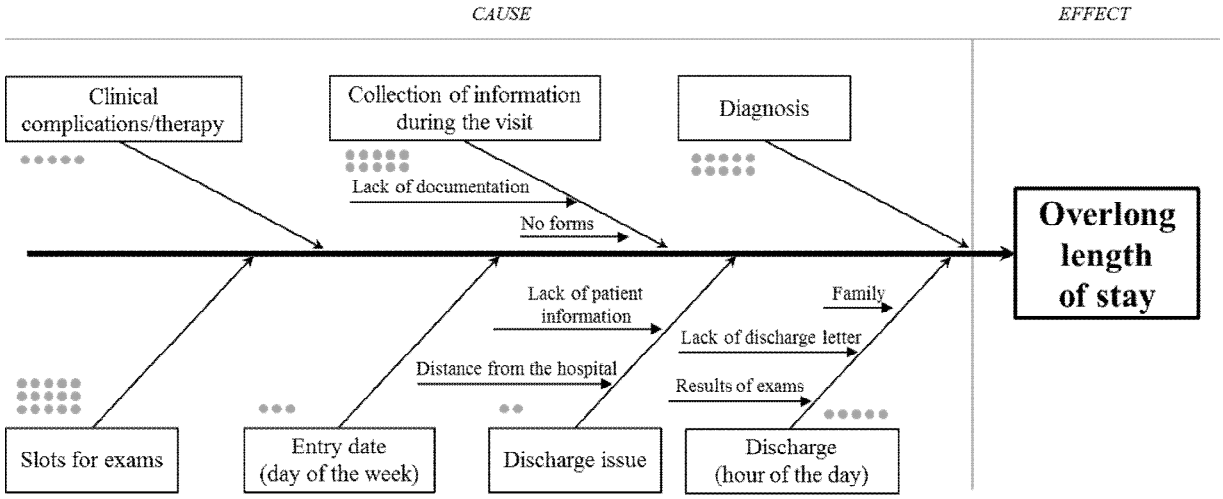


The *Measure* phase was concluded with a "Speak with data" session useful to assess whether there was a correlation between CTQ and the treatments being provided, the operators involved and planned dates of access and exit for patients. This step allowed identifying in a qualitative way a group of "vital few" to be later analyzed.

Analyze

An Ishikawa diagram (also known as "Fishbone diagram" or "cause-and-effect diagram") was the focal point of this phase of the project. The Ishikawa Diagram portrays the *root causes* of a specific problem. Root causes are usually classified into a few major categories useful to identify the sources of variation, being the most commonly used the following ones: Manpower, Materials, Machines, Methods, Mother Nature, and Measurements. To this aim, two sessions with the Quality Team were organized and run using a *brainstorming* technique: each Team member was required to reflect on and highlight the main causes underlying the CTQ (i.e., overlong length of stay). At the end of the two meetings, all the causes being mentioned were subsequently classified into a few clusters and weighted by each Team member using a 5 point Likert scale (0 = minimum; 5 = maximum in order to identify the root causes).The Ishikawa diagram resulting from these meetings is portrayed in Figure 10.

Figure 10: Ishikawa diagram



As shown, participants to this step of the project converged on a few roots for CTQ1 which were mainly organizational and administrative issues, such as an ill-defined assignation of slots to exams, and an inefficient data/information collection prior or during the visits. Overall, the most important insight was related to the possibility of impacting on CTQs just adopting organizational and administrative solutions (e.g., carefully planning patients' admissions well in advance), without interfering with how professionals provide care services.

Improve

In this phase two meetings involving all the project stakeholders (Chief Medical Officer, Ward Director, other Physicians and Nurses of the Ward, and Postgraduate students) were arranged with the specific aim to identify feasible solutions for rapid and continuous improvement.

For every root cause as identified in the Analyze phase and subsequently included in the Ishikawa diagram, the Team determined a related improvement action to be carried out, additionally identifying the persons in charge of that action and the deadlines to comply with. As a result, a complete plan of intervention was defined, and a few specific improvement actions were planned.

a) Development of a new *flowchart* to be used to plan patients' admissions and exits to and from the Ward. This helped to redefine the process of admissions and reduce waiting lists.
b) Definition of a new *medical record* to be used during the patient's examination. This renewed documentation helped professionals to efficiently gather and record data during the visits.
c) Implementation of new *visual management* tools within the Ward (e.g., a dashboard displaying Key Performance Indicators).
d) Creation of a new computer-assisted *waiting list*, which better supported the planning of future admissions.
e) Implementation of a new *protocol* for radiological examinations. This particularly supported professionals in keeping activities under control and complying with regulatory procedures.

Control

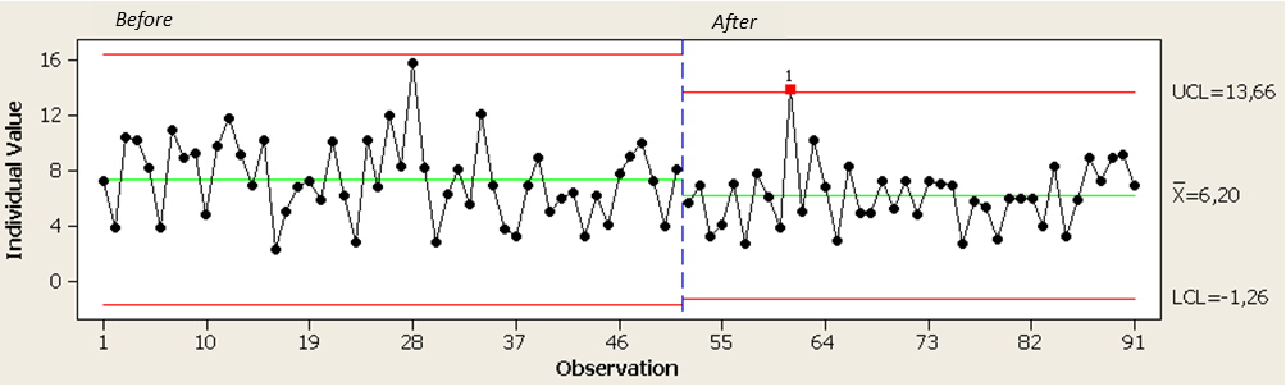
During the *Control* phase, the Team compared the results with targets, and explored all the feasible interventions needed to make the improvements sustainable over time. Data analysis showed that *process performance* increased from 38.59% (614.051 PPM) to 55% (443.389 PPM), *process sigma* increased from 1.21 to 1.64 and *process capability* increased from -0.04 to 0.11, as also summarized in Table 3.

Table 3: Key performance indicators

	Before	***After***
Process Performance	38.59%	55%
Process Capability	–0.04	0.11
Process Sigma	1.21	1.64

The process also showed improvements in mean value moving from 7.34 to 6.2 for CTQ1, as shown by the following control chart which compares CTQ1 data *before* and *after* the LSS project.

Figure 11: Control Chart before and after the LSS project



It is also noteworthy that the project led to the first audit focused on organizational and management issues for the Ward, and facilitated the planning of periodical (on a quarterly basis) meetings between the LSS Green belt and the process owners. Last, the data related to the project and all the relevant metrics explaining key results were included in a Final report delivered to the main Sponsors.

6. Discussion and final remarks

This article aimed to explore the potentialities of a combined use of Lean principles and Six Sigma tools presenting a pilot LSS project developed in a Hospital of large size. The article pursued three main aims.

First, the article meant to evaluate performance improvement in the Healthcare institution under analysis. The data we reported showed an increase in performance; more specifically the project reached its main goals in terms of process performance and process sigma improvements. Additionally the project allowed saving more than € 28,000 on a yearly basis and more than 65 days of hospitalization which are being subsequently reallocated in a different and more efficient way. This is consistent with the academic contributions suggesting that Lean and LSS may be able to simultaneously increase efficiency and quality, and decrease waste and costs (e.g., Kimsey, 2010 Robinson et al., 2012; Radnor and Osborne, 2013).

The second aim of the project required discussing the potentialities of LSS tools and principles when applied to HC organizations, as an increasing literature is urging to do (e.g., Radnor et al., 2006; Pepper and Spedding, 2010; de Souza and Pidd, 2011; Radnor and Osborne, 2013). In authors' opinion, the case study here presented provides evidence of the benefits of LSS in HC: LSS fruitfully combines and exploits both Lean *and* Six Sigma main strengths, since it helps to attack and eliminate wasteful activities, increase the quality of the services being provided, speed-up processes, reduce costs and defects, rationalize resource allocation and use. In sum, LSS provides a structured, systematic, and strategic approach to manage and plan process improvement initiatives (Hutchins, 2008; Barnabè, 2015).

Third, the article aimed at highlighting the key factors enabling a LSS intervention in a Healthcare setting. To this aim, we first discuss (see Table 4) the key learning points emerging from the project and the interviews with Team Members, the Green belt and the main Sponsors.

Table 4: Key learning points and reporting outputs

DMAIC Phase	*Key learning points*	*Reporting outputs*
Define	• We met, and discussed and understood the potentialities of applying LSS in HC *and* in this specific HC setting. • We analyzed data and current performance. The process was extremely variable and Six Sigma tools' potentials were discussed. • We understood there was a problem and mentioned possible cause. Most were wasteful activities and Lean was therefore recommended. • We developed a map of the process and reflected upon critical factors.	Project charter.
Measure	• Data collection helped to understand our operational setting. • We used LSS statistical tools to measure current performance. • We understood that the defects were higher than thought (62% of defects and 38% of process performance). • The correlation analysis between CTQ and the treatments being provided helped us to identify bottlenecks.	Several measures to be further analyzed
Analyze	• Planning activities related to patients' admission were particularly difficult. • Medical visits presented great opportunities to learn from patients and gather a lot of information on how we were performing and providing medical treatments. • We understood to have a chance to impact on CTQs just adopting administrative and organizational solutions, without interfering with the doctors and their medical activities.	Report for the Analyze phase
Improve	• We understood that most of the root causes could be tackled in the short term. • Many solutions did not require financial investments, only leading to attack waste, rationalize activities and speed-up processes. • The Analyze phase was fundamental to understand where the leverage points were and how to intervene quickly and directly on the root causes, so to attack and eliminate wasteful activities.	Report for the Improve phase
Control	• We delivered the Final report. • We organized the "first organizational audit" which was completely dedicated to organizational issues. • Monitoring activities were planned, as follows: 1. Every 3 months, the Green belt communicates CTQ values to the Process Owner, eventually scheduling Team meetings to investigate defects (if necessary and on the basis of measurements against targets). 2. Performance indicators monthly updated 3. Improvement actions already planned (e.g., Introduction of a new standard protocol to manage the patients' waiting list).	Final Report on the whole LSS project

As shown in Table 4, it is noteworthy that the discussion and analysis throughout the five DMAIC stages not only supported understanding, discussion and knowledge sharing among the participants, but also allowed collecting data, drafting new reports, and improving planning and reporting tools in use. Moving forward, the considerations reported in this article and the information gathered with the interviews clearly highlighted a few factors enabling LSS interventions, and facilitating change and improvement initiatives in a HC setting, as follows.

1) *Institutional leadership*. The LSS project was heavily sponsored and supported by a few key roles within the Hospital: Chief Executive Officer, Chief Medical Officer, Chief Financial Officer, and Ward Director. This support was sustained throughout the project and in its subsequent control phase.

2) *Communication*. The creation of a Quality Team, the meetings arranged during the project, the use of specific techniques (e.g., brainstorming) greatly supported people in communicating, also facilitating processes of knowledge elicitation and knowledge sharing.
3) *Personnel training*. Training was a key enabling factor for this LSS project, fostering learning and clarifying the main aims and characteristics of LSS in HC and in the specific context.
4) *Employee empowerment*. All the participants to the project got engaged by its main goals and played an active role in facilitating change and implementing improvement actions.

In sum, we believe that LSS represents a powerful approach for performance improvement and change management in HC organizations. In this light, it is authors' opinion that this article provides evidence, and may fruitfully contribute to the debate about the role of LSS in HC.

As to the limitations, we underline that the considerations provided in this article are based on a single case study, and may only be partially generalized, this also depending on several endogenous and exogenous factors (e.g., institutional, cultural, technical and regulatory factors). No attempt is made to suggest a prescriptive approach. Future research will help authors to further investigate LSS potentialities and the factors enabling its implementation in HC.

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