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APPLICATION OF LEAN SIX SIGMA TO REDUCE PATIENT WAITING TIME: LITERATURE REVIEW

Abstract:*Reducing patient waits is vital to respond for the increasing demand for quality health services. Toward this endeavour, the aim of this research is to explore the current situation of application of lean six sigma (LSS) techniques in the healthcare sector as a strategy to address negative effects of long waiting of patients. The study reviews the outcomes of application LSS techniques to increase patient's satisfaction with healthcare. A comprehensive review of the literature dedicated to apply LSS in healthcare is used to generate a synthesis of the literature around the chosen research aim. The review focuses on research addressed various types of issues, which can cause increasing waiting time at healthcare centres. The study confirms the significant of LSS application in reducing waiting time of patients at healthcare centres.*

Keywords: *Lean healthcare; LSS; Waiting time.*

1. Introduction

Currently, the major challenge in healthcare sector in developing world is to achieve high quality healthcare services with limited available capacities. Annual statistics data from World Bank for last recent years revealed that the healthcare sector is proxied by total health expenditures is around 11% from the Gross Domestic Product (GDP) of the world (Doğan & Unutulmaz, 2014). Long waiting times to receive care and treatment can be life-threatening and detrimental to the quality of service of healthcare (Costa & Godinho, 2016). Although healthcare expenditures are steadily increased over recent years, the healthcare services are mostly characterised by bad quality aspects (Laureani, Brady, & Antony, 2013). This is often related to persistent issues in the healthcare system such as patient waiting time, patient satisfaction, available human resources, resource utilisation and funding (Tchouaket, Lamarche, Goulet, & Contandriopoulos, 2012). Healthcare centres need to continuously innovate and improve their operational efficiency and reduce costs while offering the best service to their patients (Rothgang, 2005; Harrington, 2010; Shaw, Asomugha, Conway, & Rein, 2014). Hence, it is an interesting theme globally due to the nature of and perception of health and health care (Laureani, Brady, & Antony, 2013). From various methods and tools that used to address improvement of healthcare system performance is the using of effective quality approaches which utilised successfully by the companies in manufacturing industry (Machado, Scavarda, & Vaccaro, 2014). With using these approaches, healthcare system objectives like increasing resources utilisation, reducing waiting time, and reducing process cycle time, have been already achieved (Gowen, Stock, & Mcfadden, 2008). In the last few years, healthcare sector has significantly used lean

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thinking as a policy to improve quality of care (Souza, 2009). Patient waiting time is a common problem in the outpatient clinics. This is related to several factors including large number of patients and shortage of staff. It is considered as an indicator in the measuring of healthcare quality. Previous studies confirmed earlier that prolonged waiting times forced patients leaving outpatients clinics (Fernandes, Barry, & Palmer, 1994).

Several studies have shown that patients have to wait to get the required healthcare in both developed and developing countries (Oche & Umar, 2013). However, the waiting time is mostly varied from one country to another and from centre to centre in the same country. As an example, in USA, it was found around 1 hour in Atlanta and 2.5 hour in Michigan (Shahzadi & Shafquat, 2017). Similar situation can be found related to this issue in Malaysia (Pillay, Ghazali, & Manaf., 2017), in Vietnam (Tran, Nguyen, Minh Nong, & Tran, 2017). Although the application of LSS has been widely used in many healthsectors in different countries, its application in the field of reducing the patient's waiting time has rarely been highlighted. This shows there is an urgent need for further research to be undertaken for understanding the current status of LSS implementation regarding to this important issue. Therefore, this paper aims to explore how LSS has been applied in various public healthcare organizations worldwide to reduce the patient waiting time. This paper considers reviewing the literature on LSS applications and its associated tools to reduce patient waiting times. After having introduced the research work of this paper in this section, the general structure of the methodology used to conduct the review is presented in section 2. The third section explains the literature review related to the topic. Section 4 presents the conclusions drawn from undertaken review and recommendations for future research.

2. Methodology

The adopted methodology is a narrative review of the literature. The review is conducted in several databases; Scopus, Emerald, Pubmed, Web of Science and on hand – search in which the search consists of manual investigation of the entire contents ofa journal to determine the suitable articles which matches the required search. The literature in medical journals and in journals related to healthcare management, operations management, and quality management were subjected to review and analysis. Keywords search included “lean healthcare, Lean Six Sigma, waiting time, lean management” and the like. The review extended to the references cited in the articles. Research published before 2003 was excluded. It was noted that a yearly growth in number of publications that focuses on lean healthcare applications. This pointed out the increasing presence of lean healthcare globally. The final number of papers reviewed and analyzed to around 60 relevant work. The process for selecting the papers in this review is presented in Figure 1.

3. Literature review

LSS strategy provides manufacturing and service organisations with a systematic approach to improve quality, enhance overall performance as well as customer satisfaction (Snee, 2010). This stagey is a result from combing another two strategies: lean manufacturing and Six Sigma (Drohomeretski, Gouvea da Costa, De Lima, & Da Rosa Garbuio, 2015). The recent focus on this management strategy for gaining improvement in healthcare industry led to a huge number of publications. The presented knowledge in this published research can be used to build the structure to achieve continuous improvement, having the patient satisfactions as the main goal consists of the literature relevant to the outcomes in healthcare centres that have adopted LSS. In

this paper, the main focus is on waiting time at public healthcare organizations that normally have waiting longer than private healthcare ones (Johannessen & Alexandersen, 2018; Rosas-Hernandez, Tlapa, Baez-Lopez, Limon-Romero, & Perez-Sanchez, 2019) - The types of monitored healthcare organizations are hospitals or healthcare centers and vary among different countries.

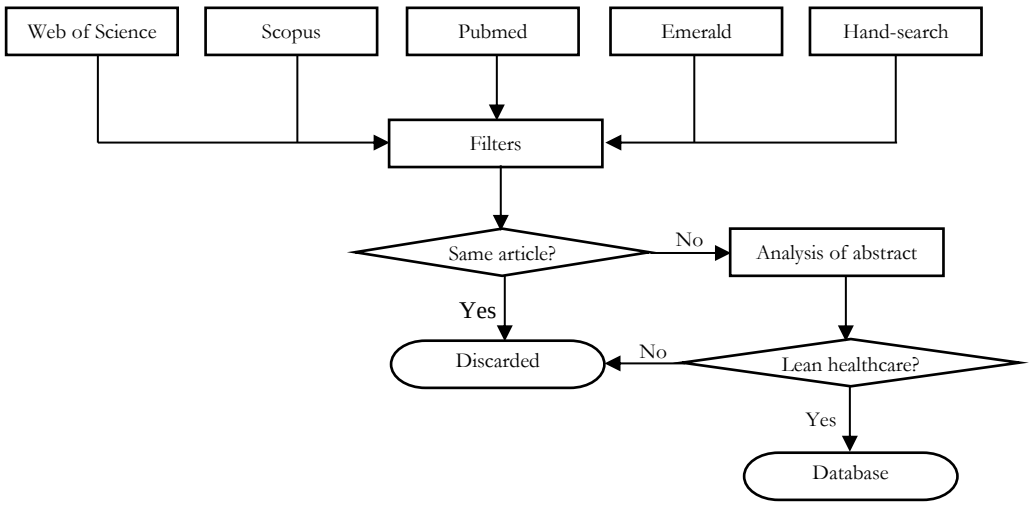

Figure 1. Schematic structure for database selection

3.1. Lean thinking in healthcare

The idea of lean originates from the Toyota Production System (TPS), a manufacturing management philosophy, aiming to reduce waste, including time-wasted, while improving customer satisfaction at the same time (Womack & Jones, 2005). Extant literature identifies seven types of wastes: transport; inventory; motion; waiting; over-production; over-processing and defects, while an eighth waste (skills) was included in a later stage (Vlachos, 2015). One of main goals of lean thinking is to eliminate time-consuming tasks. In this way, operations and processes become more productive since the value-adding proportion of working time is maximised when workload is too much; i.e. human resources remain the same (Womack, Jones, & Roos, 2003). Lean goes beyond production; it is system-wide and holistic covering all levels of the organization, including value-added activities, operations, and human capital (e.g. Tay, Singh, Bhakoo, and Al-Balushi (2017), Caldera, Desha, and Dawes (2017), Hill, Thomas, Mason-Jones, and El-Kateb (2018)). When considering lean, companies aim to increase productivity of their personnel by training them to remove time wasted and utilise their skills into a more productive way (Chan &Tay, 2018). There is a wealth of lean tools and methods available for different types of wastes and organisational types (Table 1). Tools include assessment (5 whys, A3, Value stream mapping, etc), improvement (5S, Andon, Kanban, Jidoka etc), monitoring (visual management) and holistic tools for assessment, improvement, and monitoring, including DMAIC. From those tools listed in Table 1, Kovacevic, Jovičić, Djapan, and Zivanovic-Macuzic (2016) detailed most frequently used lean tools in the healthcare sectors. However, a detailed breakdown on the use of these tools in the research which is conducted with the aim of reducing patient waiting time - the subject of the current research - will be provided in the context of this review. Lean tools and techniques are suitable to improve the health service sector

and there is an increased interest in healthcare summarised in various literature reviews. For example, Costa and Godinho (2016) reviewed relevant literature on lean and process improvement in health care and found that 35% was on leaning the health sector. D'Andreamatteo, Ianni, Lega, and Sargiacomo (2015) reviewed 243 articles and tracked an increased interest during last decade. Al-Balushi et al. (2014) reviewed 170 articles to develop a 'lean readiness' point system for healthcare.

However, not all lean projects are successful. For example, Radnor, Holweg, and Waring (2012) conducted four multi-level case studies of the implementation of lean in the English NHS and found that the application of specific lean 'tools', such as 'kaizen blitz' and 'rapid improvement events', hit some low-lying glass ceiling and produce small-scale and localised productivity gains more system-wider improvements evident.

3.2. Lean Six Sigma in healthcare

Lean is a quality-oriented philosophy while Six Sigma is a quantity-oriented tool. It was not until early 2000s that both Lean and Six Sigma get integrated together (Snee, 2010). Lean Six Sigma (LSS) a toolbox with two sets of tools that gives managers the option to use the best of them depending on the problem presented. LSS is therefore suitable for the healthcare sector due to its potential for reducing medical errors and at the same time improving patient care (De Koning, Verver, Van Den Heuvel, Bisgaard, & Does, 2006).

Consultants from General Electric implemented one of the first, if not the first, LSS project in Commonwealth Health Corporation in Massachusetts in 1998 to achieve 33% increase in radiology throughput and 21.5% decrease in costs (Thomerson, 2001). However, not all clinics can afford lean consultants, especially in developing countries. Therefore, a systematic way to implement LSS in developing countries is lacking from the literature. Glasgow, Scott-Caziewell, and Kaboli (2010) reviewed lean in healthcare and found 47 relevant articles, including 20 Six Sigma projects, and 5 LSS projects. Dellifraine, Langabeer, and Nembhard (2010) reviewed 177 articles on LSS in healthcare over a decade and found 34 with empirical results and just 11 articles with tests of statistical significance.

DelliFraine et al. (2010) concluded that there is weak evidence that LSS alone can produce significant results. Shirazi and Pintelon (2012) reviewed 120 papers about LSS in health care and found most to be case studies. Liberatore (2013) reviewed 88 Six Sigma healthcare reports and articles including admission, discharge, medication administration, Operating Room (OR), cardiac and intensive care. Liberatore (2013) found 38% to focus on process time and while 67% had initial improvement, only 10 % reported sustained improvement.

Koeijer, Paauwe, and Huijsman (2014) and Radnor et al. (2012) addressed criticism that LSS redirects clinical practice away from patient-centered care toward more administrative and management tasks and proposed that LSS should create a culture of continuous improvement based on shared perceptions of employees on quality, efficiency and innovation. Only 22 out of 243 articles (9%) reviewed by D'Andreamatteo et al. (2015), were on Six Sigma and just two articles in developing countries. Review of D'Andreamatteo et al. (2015) revealed a gap in our understanding how LSS relates to organisational culture and people management. In this research, an ivitation to scholars to explore further the potentiality and the weaknesses of lean, above all as for the magnitude of investments required and for the engagement of the whole organization it represents increasingly strategic choice, whilst health professionals, managers and policy makers could and should learn from research how to play a pivotal role for a more effective implementation of lean in different health contexts.

Table 1. Table Lean Tools and Methods

Lean tools and methods	Definitions
Assessment	
5 Whys	A technique used to find the root cause and effect relationships of a defect or a problem by asking "why?" at least five times.
A3	A systematic approach used in process of problem solving based on the concepts of PDCA; plan, do, check, and act.
ishikawa diagram	Ishikawa diagrams which is also known by other names: fishbone diagrams, cause and effects diagrams, and fishikawa, is used to identify the potential reasons which are caused a specific problem.
Process mapping	A comprehensive guide involves defining all the activities and decisions in a process.
Value stream mapping	A flowchart method to depict, analyse and improve the flow of materials and information necessary to deliver a product or service to a customer.
gemba walking	A popular management process technique based on visiting the place where the work is done to understand and solve of the problems that affect that work through collaboration with front line employees there.
Improvement	
5S's	A workplace organisation method relates to the Japanese words (Sort, Straight, Shine, Standardise, Sustain).
team approach to problem solving	An in-depth approach to manage and understand of a problem that needed more analytics.
Spaghetti diagram	A tool to analyse workflow and flow of materials to expose the waste on transportation, motion and waiting time.
Workload balancing	A concept involves distribution of workloads between the sub-processes to optimise usage of resources, throughput maximisation, response time minimisation.
continuous flow	Is an approach that aims at continuing to add value through production processes without ever stopping.
andon	A tool referring to a system to indicate the status of that system, machine or process in it.
rapid process improvements events/Kaizen event	Any action in production process or service delivery intents improving an existing process.
Jidoka	A principle based on "automation with a human touch" to enable the worker to stop the machine or the process and consequently preventing defective parts from being produced.
Pull system/Kanban	An approach to manage supply chain by allowing "just in time" delivery of resources.
one-piece-flow	Production of the product moves from one process to next process only one piece at a time.
Mistake-proofing (Poka-yoke)	A method to prevent defects from occurring in the production processes.
Process redesign	A management strategy focusing on the analysis and design of a process to achieve improvement in output.
Production leveling (Heijunka)	A technique aims reducing wastes in production to help firms meeting demand.
Physical work setting redesign	Reworking of a process to yield significant improvement in the output.
Standardised work	A work in which the job's sequence has been efficiently organised and performed uniformly to achieve a required output.

Table 2. Table Lean Tools and Methods (continued)

Monitoring	
Visual management	A technique includes using visual aids to manage available resources for production.
Assessment/Improvement/Monitoring	
Siz Sigma DMAIC (define-Measure-analyse-improve-control)	Set of techniques and tools to improve the production processes or perform service.
PDCA (Plan-do-check-action)	A four-step management method enables continuous improvement of their process, products or services.

Al-Owad, Karim, and Ma (2014) applied LSS approach to resolve the patient flow problems in hospital emergency departments and found that improvements depend on engaging frontline workers, establishing leadership commitment, and analyse patients needs. Bhat and Jnanesh (2013, 2014) used LSS to reduce turn-around time of health records preparation process in a hospital in India and in out-patient department service of a rural hospital. Bhat and Jnanesh (2014) reported a reduction of cycle time from 4.27 minutes to 1.5 minutes. Bhat, Gijo, and Jnanesh (2014) reported similar results in another study on Health Information Department of a Medical College hospital in India. Chiarini (2012), Chiarini and Bracci (2013), Chiarini (2014), and Chiarini and Cherrafi (2017) reported substantial savings in time and cost from LSS implementation in Italy. Cima et al. (2011) applied LSS in High-Volume Tertiary-Care Academic Medical Center and found that, across 3 surgical specialties, process redesign resulted in substantial improvements in on-time starts and reduction in number of cases past 5 pm. Further, substantial gains were achieved in nonoperative time, staff overtime, and ORs saved. These changes resulted in substantial increases in margin OR / day. Jin, Switzer, and Agirbas (2008) applied LSS in healthcare logistics centre at North Mississippi Health Services and achieved $800k annual savings due to better utilisation of space and timely delivery of the right items.

Kovach, De la Torre, and Walker (2008) reported operational efficiency improvements and enhanced patient care with the application of LSS in Texas Medical Centre. Aleem (2013) reported LSS implementation in Hertel Elmwood Internal Medicine Centre at New York, USA and Sigma value for wait time for examination room improved from 21.08 to 17.18; and the critical to quality (CTQ) measure, which was percentage of patients waiting more than 20 minutes, went down from 38.6% to 23.7%. Langabeer, DelliFraine, Heineke, and Abbass (2009) found the LSS needs goal clarity and measurement to achieve operational efficiency improvements, highlighting the role of personnel engagement and lean culture. Laureani, Brady, and Antony (2013) presented five projects of LSS in an Irish hospital and reported improvements in the efficiency and effectiveness of clinical and administrative processes. Neufeld et al. (2013) applied LSS to reduce discharge paperwork of patients in Integrated Inpatient Rehabilitation Program (CIIRP) and increased the required discharge elements from 61.8% to 94.2% and the percentage of charts that were 100% complete increased from 11.9% to 67.8%.

Niemeijer, Trip, Ahaus, Does, and Wendt (2010) reduced LOS of trauma patients in University Medical Center Groningen, the Netherlands from 10.4 days to 8.5 days. Niemeijer, Trip, De Jong, Wendt, and Does (2012) assessed the impact of LSS over 5 years in a University Medical Center and found that LSS helped indeed reducing cost and improving quality. Niemeijer et al. (2013) used LSS to reduce prolonged Length of Stay

(LOS) for hip fractures in the elderly multidisciplinary clinical pathway down to 4.2 days (-31%) and the average duration of surgery by 57 minutes (-36%). Pocha (2010) presented a case of LSS at a tertiary care medical centre in New York, USA and reported improvements in number of X-rays and substantial cost savings. Van den Heuvel, Does, and De Koning (2004) suggested LSS for rapid access and no waiting times, while reducing defects means less complication. Stanton et al. (2014) applied LSS in the emergency department (ED) of a large Australian hospital and found it to improve patient flow from the ED to the wards and to have positive implications for some staff. Sunyog (2004) applied LSS in DSI laboratories and achieved more than $400k savings during the first year. Vest and Gamm (2009) reviewed nine studies in LSS in Studer Group intervention on topics such as surgery turnaround time, clinic appointment access, hand hygiene compliance, antibiotic prophylaxis in surgery, scheduling radiology procedures, catheter-related bloodstream infections, meeting Centres for Medicare and Medicaid Services (CMS) cardiac indictors, nosocomial urinary tract infections, and Operating Room (OR) throughput. Yamamoto, Malatestinic, Lehman, and Juneja (2010) used LSS to improve the timing of inpatient insulin administration related to meal delivery and the scheduling of radiology tests and demonstrated that the institution met goals for most primary outcome metrics. Yu and Yang (2008) achieved and sustained a drastic reduction in average waiting time in hospital registration.

Black (2009) combined LSS with realistic evaluation, a methodology that promotes change by assessing and considering the individual characteristics of an organization's social environment, successful and sustainable process improvement is more likely. Fache and Faulkner (2009) described how LSS tools such as Suppliers, Inputs, Process, Outputs, Customers (SIPOC) tool and DMAIC helped the 304-bed Floyd Medical Center, Georgia, USA, to achieve $15 million in improvement in 27 months and a marked change in culture regarding accountability and people engagement. Gayed, Black, Daggy, and Munshi (2013) applied the Vision-Analysis-Team-Aim-Map - Measure-Change-Sustain (VA-TAMMCS) model in joint replacement surgical procedures at the Richard L. Roudebush Veterans Affairs Medical Center, Indianapolis, Indiana and achieved Length of stay decreased from 5.3 days 3.4 days (36%) and an estimated return on investment of $1 million annually. Kuo, Borycki, Kushniruk, and Lee (2011) proposed a new model called healthcare LSS that integrates Lean and Six Sigma methodologies to improve workflow in a postanesthesia care unit.

Carboneau, Benge, Jaco, and Robinson (2010) applied DMAIC to low increase hygiene compliance by healthcare workers and reduce hospital-acquired infections to patients in Albuquerque, New Mexico and within 12 months, achieved 51% decrease in methicillin-resistant *Staphylococcus aureus* (MRSA), which according to their estimations correspond to 2.5 lives and US$276,500 cost savings. Chassin (2008) reported the results of LSS and DMAIC in Mount Sinai Medical Center in 2000. Achievements included: 91% defect reduction in Cardiac Care and $5M annual savings, 85% defect reduction in Chemotherapy and $1.7M annual savings and 90% defect reduction in OB / GYN with $400k annual savings. Gijo and Antony (2013) applied DMACI to reduce patient waiting time in the outpatient department (OPD) of a specialty hospital in India and achieved to reduce waiting time from 57 min to 24.5 min and the standard deviation was reduced to 9.27 from 31.15 min. Proudlove, Moxham, and Boaden (2008) reported DMAIC was among the most useful LSS tools that NHS in UK can apply. Yeh, Lin, Su, and Wang (2011) applied LSS and DMAIC to improve the medical process of acute myocardial infarction. Cycle time decreased by 58.4% below to standard value (90). Process cycle efficiency increased from 32.27

to 51.81%, and the average days of hospital stay decreased by 3 days. Montella et al. (2017) used DMAIC to improve performance of the knee replacement surgery.

Improta et al. (2018) presented a case study on using lean methodology assessment, in particular Value Stream Map (VSM) and 5S to reduce waiting times of all patients who had access to the various services including radiology, clinical analysis laboratory, and transfusion at the emergency department of AORN Cardarelli. The results confirmed that the lean tools interventions lead to improvement in patient's throughput times.

Similarly, Johannessen and Alexandersen (2018) used Value Stream Map (VSM) and unsophisticated analyses for identification of sources that waste time and consequently cause waiting times and increase wait lists across a range of specialties. The resultsindicated that the waiting time across all clincis was decreased after six months when the lean tools have been set in action.

A case study of Furterer (2018) used the lean six sigma DMAIC approach to improve throughput of emergency department which measured by reducing the patient's length of stay. Findings from the research showed that the target "length of stay" has reduced 30% in only three months.

Research conducted by Godley and Jenkins (2019) used DMAIC framework with pre-/postintervention design to decrease wait times and improving patient satisfaction in the vascular interventional radiology department. The outcomes of this study have yielded a significant reduction in wait times ($P < .0019$). The research of Kovach and Ingle (2019) focused specifically on the application of process analyses tools and techniques to identify and prioritize the main reasons of waste and consequently develop and implement the improvement solutions. The using of suggested structured improvement approach lead to decrease patient cycle time by about 20%. The latest studies published in Mexico (December 2019) dealt with how to use the lean healthcare and DMAIC approach to reduce the number of wastes in public hospitals there. Rosas-Hernandez et al. (2019) applied this approach to reduce five wastes type there; defective identification, redundant processing, unnecessary Inventory, transportation waste, and lead time.

3.3. Lean Six Sigma and simulation in healthcare

Simulation modelling is possible solution offers increasing the efficiencies when combined with LSS. The combination of Lean Six Sigma and simulation modeling has been used in different sectors of manufacturing process with increasing adopting this strategy over all the world as noted in different research work. The reader can find overwhelming amount of such research work in the past decade. Several studies have applied simulation to improve the healthcare. For example, Young (2005) suggested that simulation and lean can help healthcare to explore waste-free patient pathways. Cooper, Brailsford, and Davies (2007) proposed simulation to deal with queuing for resources and resource constraints. Kumar and Shim (2005) used computer simulation for surgical care process reengineering and Van Berkel and Blake (2007) simulated capacity planning and wait time reductions in surgical care. Golmohammadi (2016) developed a prediction model to help reduce Emergency Department boarding in USA. Kergosien, Bélanger, Soriano, Gendreau, and Ruiz (2015) developed a generic discrete event simulation-based analysis tool to improve Emergency medical services. Rohleder, Bischak and Baskin (2007) simulated patient flow at an outpatient orthopaedic clinic in Calgary, Alberta to reduce waiting time and congestion. Alike lean was integrated with Six Sigma to achieve both reduction of waste and improvement of accuracy, several studies reported the integration of LSS with simulation. The obvious advantage is the visibility of results especially in a sensitive environment that changes may have critical

repercussions if not implemented correctly. The simulation allows the experimentation and testing of several solutions before implementing it. This helps the employees to engage more by foreseeing the results and criticizing the solution before it changes the way they operate in healthcare. As such, LSS-simulation is more than an administrative tool, but it can become accustomed to doctors and nurses too. Johnson (2004), and Khurma, Bacioiu, and Pasek (2008) applied LSS and the simulation to redesign emergency departments. The better allocation of physicians reduced the waiting time of patients. Setijono, Naraghi, and Ravipati (2010) also achieved considerable reduction in the patient's waiting time and in the total time that patients stayed in the hospital. Lin, Patrick, and Labeau (2014) reduced patients waiting time by 23.7% in average in outpatient eye clinic in Singapore. Huang (1994) combined LSS and simulation to improve phlebotomy process in the emergency department / of the Niagara health system and reduced the flow time of the process by seven minutes. Proudlove et al. (2008) applied LSS in NHS, Southard, Chandra, and Kumar (2012) simulated the use of RFID and DMAIC. Celano et al. (2012) and Chaurasia, Garg, and Agarwal (2017) combined LSS and simulation to improve the quality of patient care. Khurma et al. (2008), and Mandahawi, Shurrab, Al-Shihabi, Abdallah, and Alfarah (2017) simulated the emergency room process to verity lean improvements before implemented them. Yao (2017) simulated LSS to improve MRI efficiency in hospital settings. Kieran. Cleary, De Brún, and Igoe (2017) used simulation and LSS to improve drug round efficiency and release nursing time. Montella et al. (2017) applied LSS and simulation to reduce the risk of healthcare – associated infections in surgery departments. Meguerdichian et al. (2017) applied LSS and simulation to improve operating room turnover. To improve of patients' experience over their emergency department stay, Khurma et al. (2008) applied LSS and the simulation in the emergency department in one Canadian hospital. The redesigning process of the department revealed about several improvements in the front-end process of the department. Arafeh et al. (2018) described the application of combining lean six sigma and simulation modelling based approach to address patient discharge time problem in king Hussein cancer center in Jordan. They found that application of their suggested approach reduced the patent discharge time by 54%.

4. Results

4.1. Statistics

The review showed that applying of LSS techniques in the healthcare has significant impact on care and organisation aspects, promoting advantage in terms of reducing delays and increasing patient flow. In addition, the review highlighted the LSS roleadopted by different healthcare organisations in waste elimination, increasing impact on quality, cost, and satisfaction of both employee and patients. Figure 2 shows that using LSS to assess and improve patient waiting time gained significant importance since 2001, when many published research began to occur. The literature review covered the period from 2001 until the year of conducting the survey, 2018. From that figure, it has been noted that years 2014 and 2017 have peak of publications, with 8 publications for each one, which represents 26 % of the total number of publications in the sample which considered in the current review. From 2004 onwards, this research area has new growth of publications, and an upward trend over the above-mentioned period. Considering the 60 research work that were selected and also published over the period 2001 to 2018, and based on the methodology shown in Figure 1, Table 2 shows the research which involved improve patientflow 43.3 % (26 articles), organization efficiency 33.3 (20 articles), patient safety

and employees satisfaction 15%(9 articles), cost effectiveness 5 % (3 articles), and quality in services 3.3 % (2 articles). In healthcare system, the Emergency Department (ED) is considered is highly complex unit because it serves the society's primary medical care. In this review, it seems the researchers were well positioned to focus on this unit and the design and implementation of robust ED projects was challenging. As can be seen in Table 2, around 15 % (9 articles) addressed improving ED performance in comparison to other areas of health promotions in the hospitals. Based on the research conducted in current literature review, and the application of the Bradford's law of scattering on this research, the results shows the relationship between the set of research targeted in this review and its productivity. For this purpose, the scholarly contributing the most citations were considered, which set on number of citations per article; at least 50 times since publication. It resulted in 19 articles which accounted for 72% of total citations. The highly citied articles are presented in Table 3. Through relevant current literature, lean six sigma DMAIC approach (Define, Measure, Analyze, Improve, and Control) has been widely applied across the health care sectors. DMAIC approach clearly demonstrated as a structured problem-solving technique can achieve competitive advantages and efficient decision-making capabilities within this industry. In existing literature review, it was found around 15 studies applied DMAIC to solve healthcare problems. Previous studies have confirmed that DMAIC is equally applicable to health sector organizations (Rosas-Hernandez et al., 2018).

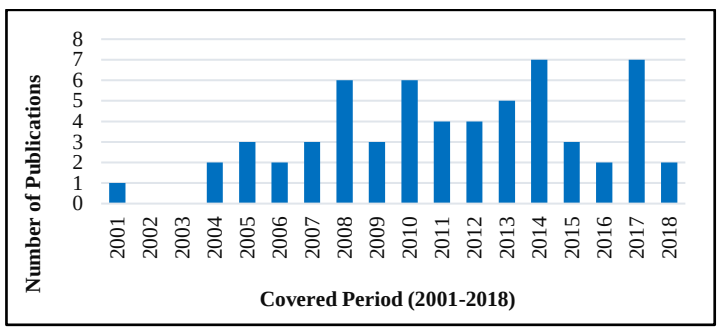

Figure 2. Evolution of publications using LSS to reduce patient waiting time over the period (2001 to 2018)

Table 2. List of subjects dominated in the articles, from 2001 to 2018

Subject	Number of Publications	Study Site	
		Hospital	Emergency Department
Improve Patient Flow	26	21	5
Organization Efficiency	20	18	2
Patient Safety and Employees Satisfaction	15	13	2
Cost Effectiveness	3	3	0
Quality in Services	2	2	0

4.2. Literature gap

Although the outcomes of the application of LSS as a strategy to improve performance of health care systems are measureable and mostly stated numerically or given as improvement rates, only few studies presented results from lean initiatives, but methodologically these studies are not comparative and included often self-

researchers observation. Most reviewed papers introduce only a limited view of the prospect benefits and limitations of LSS in healthcare. Actually, there is no research was found criticizing the LSS applications in the healthcare. Therefore, more rigorous research approaches based on empirical evidences are required to show the realeffects of LSS applications and also understand the factors affecting the success and sustainability to apply this strategy in healthcare. Further research is needed to confirm whether the LSS applications when reduce patient waiting times the quality patient care is maintained or not? As we can note, from above brief literature review, still quite of few healthcare organisation world over implemented this strategy alone, as a most effective way to eliminate the waste and then improving the process. Several researchers have pointed out the benefits of combining LSS with other techniques (e.g. simulation analysis) improving performance making healthcare system more efficient. In fact, the research community is still rarely used such combination in practice. Although there is extensive literature is reducing prolonged waiting times, only but few studies focus on developing countries. Leaning the healthcare system of developing countries might be the only improvement possible, yet there is little empirical guidance on how to achieve leaning of the healthcare system. Since in developing countries, there would be fewer lean consultants to implement the lean Six Sigma, and less resource to implement changes, the presented models in these studies provide feasible solutions for developing countries clinics. They show how LSS can assist in convincing involved parties to implement improvements. Another major contribution for these studies is that they do not focus on improving waiting time only, but it also takes into account the cost to serve and the fair balance of personnel workload, a factor that has been rarely undertaken in the literature.

5. Conclusions and Recommendations

This research aimed to review the literature on application of LSS to reduce patient waiting time in healthcare system. The goal was to identify the key elements and aspects regarding the applicability of this lean strategy in addressing the issue of increased patient throughput and reduced waiting time, as well as research limitations. Regarding this public health issue, the research confirmed that applications of LSS widespread in United States, United Kingdom, and recently in other countries while still few attempts in developing countries in adopting this strategy to play an important role in improvement patients waiting time. It emphases the necessary for further research on the applicability of LSS in healthcare in developing countries. This research stated that a significant reduction in-patient waiting time and consequently in waiting cost is achievable with proper implementation of LSS. In general, it sought the main impacts from application of LSS to reduce waiting time in health are increasing productivity and health service effectiveness, reducing costs, and increasing each of patient and employee satisfaction. The present research has some limitations. First, the review of papers was made from reading the abstract of each paper; consequently, it cannot be claim that the abstracts accurately express the contents of the paper. Second, it is expectable that some papers not have been listed in the review due to difficulty in capturing by the search for keywords adopted.

Future research can be directed their efforts toward intervention of industry 4.0 applications -internet of things (IoT) - in LSS applications to reduce patient waiting time. This research proposal enables managing different types of information in a short period of time, which is increasingly present in this universe. Also, the relation between the waiting time, quality, and costs must be better equated. This need surpassing the

purely qualitative approaches. Considering well these factors in a systematic approach may be will be provided greater applicability to lean healthcare.

Table 3. Highly cited paper sorted by citation times

Author(s)	Journal	Citations
Cima et al. (2011)	Journal of the American College of Surgeons	277
Van Berkel and Blake (2007)	Health Care Management Science	202
Rohleder, Bischak, and Baskin (2007)	Health Care Management Science	104
Cooper, Brailsford, and Davies (2007)	Journal of the Operational Research Society	87
Carboneau et al. (2010)	Journal for Healthcare Quality	75
Chiarini (2012)	Learning Health Systems	70
Niemeijer et al. (2010)	Journal of Trauma and Acute Care Surgery	69
Young (2005)	Health Care Management Science	69
Bhat, Gijo, and Jnanesh (2014)	International Journal of Productivity and Performance Management	67
Laureani and Antony (2010)	International Journal of Productivity and Performance Management	66
Oche and Umar (2011)	Journal of Public Health and Epidemiology	63
Laureani, Brady, and Antony (2013)	Leadership in Health Services	62
Gijo and Antony (2013)	Quality and Reliability Engineering International	61
Gowen III, Stock, and Mcfadden (2008)	International Journal of Production Research	61
Stanton et al. (2014)	International Journal of Human Resource Management	55
Khurma, Bacioiu, and Pasek (2008)	2008 Winter Simulation Conference	54
Pocha (2010)	Queensland Mental Health Commission	52
Chassin (2008)	Mount Sinai Journal of Medicine	51
Southard, Chandra, and Kumar (2012)	International Journal of Health Care Quality Assurance	51

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