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Abstract

Purpose- The purpose of this paper is to conduct an empirical study derived from previous literature from the perspective of benefits, tools and techniques, Continuous Improvement (CI) and Quality Improvement (QI) methodologies, and Critical Failure Factors (CFFs) of Lean and Six Sigma (SS) in the National Health Services (NHS).

Design/Methodology/Approach – A literature review was carried out to identify previous findings, empirical data and critical variables concerning LSS in Healthcare for over ten years. Secondly, primary research in quantitative surveys were carried out with 110 participants who have experience using Lean and SS in the NHS.

Findings - There are 32 tools and techniques, 36 CFFs, 8 CI and QI methodologies and 18 individual benefits across five different improvement categories cited in this paper. Lean and SS have evolved into common practices within the NHS and now have an established list of tools and techniques frequently employed by staff. Lean and SS are considered robust CI methodologies capable of effectively delivering extensive benefits across many different categories. The NHS must overcome a sizeable amount of highly important CFFs and divided organisational culture.

Originality/Value - This paper has developed the most extensive empirical study ever produced on LSS in the NHS and has expanded on previous works to create new and updated research. The findings produced in this paper will assist NHS medical directors and practitioners in obtaining an up-to-date insight into Lean and SS's status in the NHS. The paper will also guide the NHS to critically evaluate their current CI strategy to ensure long term sustainability and deliver improved levels of service to patients

Keywords: Lean, Six Sigma, Lean Six Sigma, NHS, Benefits, Tools and Techniques, Critical Failure Factors

Paper Type – Research Paper

1. Introduction

For the past two decades, there has been a growing interest in the healthcare sector that focuses on building a sustainable healthcare system (Sunder et al., 2020; Kroezen et al., 2018). In today's context, the National Health Service (NHS) in the United Kingdom (UK) is facing an unprecedented crisis, with demand for services significantly exceeding supply and resources being constantly diminishing that leads to a shortage in the staffs exemplified by 43,000 nursing vacancies and further accounting for more than 50% of NHS trusts being understaffed by 10% (Duncan, 2021; Glasper, 2020; Buchan et al., 2017; Robertson et al., 2019). This crisis is further intensified with the increase in the patients' waiting time of about 4.4 million in total, with an additional of 10,000 patients each month (Barker, 2018). This has led to a drop in the overall key performance targets from 95% to 86.5% (Keogh et al., 2018; Donnelly, 2016; Leys, 2014). In addition to this, medication errors result in costs of over £2.5 billion a year which places unnecessary additional pressure on the NHS (Torjesen, 2019). Alarmingly, 1 in 20 hospital deaths is recorded as preventable, translating into thousands of patients needlessly losing their lives every year (Hogan et al., 2012). Indeed, whilst there is evidence that both Lean and SS have delivered immense benefits in the healthcare sector, further research on Lean and SS application in the NHS may unearth a solution to the prevailing challenges (Improta et al., 2015; Matthias and Brown 2016).

A number of studies related to lean and six sigma have been undertaken by academicians and researchers worldwide, particularly in the manufacturing and service sectors (Antony et al., 2019; Habidin, 2013; Akbulut-Bailey et al., 2012; McAdam et al., 2011; Ahuja and Khamba, 2008). However, the adoption and implementation of lean and six sigma in the healthcare sector are still in the nascent and development stage (Improta et al., 2015; Schweikhart and Dembe, 2009). Although Lean, SS and Lean Six Sigma (LSS) are some of the popular methodologies in continuous improvement, it is reported that most of the studies in healthcare are conceptual and not empirical (Henrique and Filho, 2020; Seidl and Newhouse, 2012). This study will also be one of the first major empirical studies which compare the effectiveness of Lean and SS within the NHS since 2012 (Antony and Kumar, 2012). Additionally, no empirical study has ever been produced which compares the effectiveness of lean, six sigma, and lean six sigma (LSS), particularly in delivering benefits in the NHS across the five improvement categories, such as operational excellence, financial performance, customer focus, people and compliance (Niñerola et al., 2020; DelliFraine et al., 2013; Liberatore, 2013). Therefore, there is a critical research need to study the adoption

of quality improvement tools, particularly lean and six sigma in NHS and overcoming major challenges to enhance customer satisfaction and providing effective and efficient health services.

This study aims to examine the current status of Lean and SS within health services. Increasing costs, pressures on capacity, issues with patient safety, unanticipated pandemics all require the NHS to operate efficiently and effectively and utilise continuous improvement methods to meet their challenges. The findings will be advantageous for NHS medical directors and clinicians by facilitating an increased and up-to-date understanding of each methodology's potential impact and present-day standing. In summary, this study aims to present an overview and understanding of the quality improvement strategies used for continuous improvement at NHS. More specifically, research is intended to ascertain the answers to the following Research Questions (RQs).

RQ1: What are the most common continuous improvement and quality improvement strategies used by NHS staff?

RQ2: What are the most common and least commonly utilised Lean and SS tools and techniques in the NHS?

RQ3: How effective is Lean, SS and LSS for driving improvements throughout each of the five categorical benefits - Financial Performance (FP), Operational Excellence (OE), Patient Focus (PF), People (P), and Compliance (C) across the NHS?

RQ4: What are the essential CFFs of Lean and SS implementation in the NHS?

RQ5: Has Lean or SS changed the culture of the NHS?

In order to answer these aforementioned research questions, the authors will utilise the following methodology; 1) a literature review was carried out to identify previous findings, empirical data and critical variables concerning LSS in Healthcare for over ten years and 2) primary research utilising quantitative surveys was carried out with 110 participants who have experience using Lean and SS in the NHS.

The remainder of the paper is as follows. The literature review is presented in Section 2, followed by a description of the research methodology in Section 3. Section 4 summarises the key findings followed by discussion, implications and limitations in Section 5. Finally, the conclusions and future research agenda of the study are discussed in Section 6.

2. Literature review

Continuous improvement (CI), which is regarded as one of the pillars in the management system, has been defined as "a systematic method of actively identifying and applying new ways of doing work that repeatedly delivers process performance benefits and creates value for stakeholders" (Anand et al., 2009). Several CI methodologies have been adopted to deliver better healthcare services quality (Buttigiet et al., 2016). For instance, the TQM approach has been adopted to prevent errors systematically, thereby enhancing operational excellence and organisational performance for health services (Rooney, 1992; Kim and Johnson, 1994; Counte et al., 1995). Many health care organisations have widely accepted kaizen Events that generally consist of consecutive 3 to 5 days as a highly effective CI approach that allows cross-functional teams to rapidly identify and implement solutions (Yu et al., 2021; Culcuoglu et al., 2012). Similarly, Rapid Improvement Events (RIE) and Plan-Do-Check-Act (PDCA) strategies have also been applied in healthcare to bring about continuous structured quality improvement (QI) (Taylor et al., 2014). In addition to this, the Lean methodology helps improve employee engagement. Also, Lean thinking can improve cycle and lead times by transforming waste into value (Dombroski and Mielke, 2013; Barney, 2002). SS is a statistical management strategy invented by Motorola in 1986, which has enabled healthcare providers to measure their respective systems and processes (Dasgupta, 2003).

Moreover, SS reduce variability and establish control mechanisms based on a deep understanding of customer requirements. Tolga et al. (2007) point out that as the sigma level increases, so does the healthcare system's performance level. Later, Antony and Kumar (2012) highlighted Lean, SS and LSS as robust CI methodologies that are frequently used in healthcare to enhance efficiency and effectiveness. Furthermore, LSS was created by integrating the philosophies of both Lean and SS (George, 2002), a highly effective methodology focusing on the Voice of Customer. Besides, LSS promotes a unified organisational culture whilst simultaneously reducing waste and variation in the processes (Antony et al., 2019; Laureani et al., 2010). Table 1 summarizes the definition, differences, and similarities among the Lean, SS and LSS (Bhat et al., 2021; Dahlgaard and Dahlgaard-Park, 2006; Drohomeretski et al., 2014; Salah et al., 2010; Sunder, 2013)

Table 1: Summary of Lean Vs Six Sigma (SS) Vs Lean Six Sigma (LSS) methodologies

Particulars	Lean	SS	LSS
Definition	A set of management practices to improve efficiency and effectiveness by eliminating waste	A method that provides organizations tools to improve the capability of their business processes	A fact-based, data-driven philosophy of improvement that values defect prevention over defect detection
Principle	Increase efficiency by reducing waste and enhancing the process flow	Increase efficiency by reducing variance, defects, shifting process average, determining optimal operating conditions	Improve the efficiency and quality by customer focus, root cause analysis, elimination of variation, teamwork and cultural change
Expectation	Rapid efficiency improvement	Rapid accuracy improvement	Rapid quality improvement and cultural transformation
Focus	Flow	Problem	Customer, process and employee
Major Outcome	Reduced flow time	Uniform process output	Increase speed, improve accuracy, cultural change and flexibility
Criticism	Statistical or system analysis is not valued	System interaction not considered	Expensive, more structured, and rigid approach
Methodology	Value Stream Mapping (VSM) (Primary)	Statistical Process Control (SPC) (Primary)	VSM and SPC
	JIT (Just-in-time)/ Pull (Secondary)	DMAIC (Define, Measure, Analyze, Improve, Control)/ DMADV (Define, Measure, Analyze,	DMAIC/ DMADV (Secondary)

Particulars	Lean	SS	LSS
		Design, Verify) (Secondary)	
Project Length	1 week to 3 months	2 to 6 months	2 to 6 months
Project selection	Driven by VSM	Driven by BPM (Business Process Management) and Gap analysis	Driven by customer focus and complexity
Analysis techniques	Trend (traditionally) to be geared toward descriptive displays (e.g., process maps), root cause analysis, and mistake proofing	Trend (traditionally) to be geared toward statistical data analysis, controlled experimentation, and optimization	Trend (traditionally) to adopt adequate analysis techniques from both Lean and SS approach
Investment	Low based on training and infrastructure	High based on training and infrastructure	High based on training, infrastructure and cultural change
Organizational infrastructure	• Informal • Mostly ad-hoc, no or little formal training	• Formal [Champions, MBB (Master Black Belt), BB (Black Belt), GB (Green Belt)] • Dedicated resources, broad-based training	• Formal (Champions, MBB, BB, GB) • Dedicated resources, broad-based training • Learning organization structure
Differences	• Identification of end-to-end value stream of the process • Creating visual workplace • Focus on	• Statistical analysis of the problem root causes • Focus on reducing variation for defect-free process • Control over	• Visual and statistical analysis • Concentrating and speed and accuracy simultaneously • Simple tools for waste reduction

Particulars	Lean	SS	LSS
	eliminating waste and improving the flow • Rapid improvements	upholding/sustaining the improvements • Breakthrough improvement	• Advanced tools for variation reduction • Sustaining the improvement through cultural transformation
Advantages	• Reduction in cycle time, WIP (Work-in-Process), cost, delivery time, space, utilization of equipment, workforce • Improved productivity	• Reduction in defect and cost • Improvement in productivity, customer satisfaction, market share, and process output	• Faster and higher quality output • Sustainment of results through Cultural change • Customer delight • Optimal utilization of available resources
Disadvantages	• Statistical and system analysis not valued • Process instability and incapability • People issue	• Long project duration • Lack of specific speed tools • System interaction is not considered since processes are improved independently.	• Absence of clear guidelines in the early stage of implementation • Lack of clear road map for implementation • Lack of structured curriculum
Set of Tools and Techniques	• Kanban • kaizen • Visual workplace • Single minute exchange of die (SMED) • Single piece flow	• Hypotheses testing • Control charts • Regression • Design of experiments • Measurement analysis	• Adequate and best tools from both Lean and SS toolbox depending on the complexity of the problem

Particulars	Lean	SS	LSS
	• Layout planning • TPM (Total Productive Maintenance) • 5S	• Capability analysis • Analysis of means and variance	
Common tools	• Brainstorming • Process mapping • Standardization • Mistake-proofing • Seven quality tools		
Similarities	• Customer focus • Continuous improvement culture • Commitment and active involvement required • Employee engagement • Process improvements • Cross-functional deployment • Productivity/Cost saving • A dedicated and structured approach • Increase effectiveness • Includes basic root cause analysis, problem-solving, process analysis, and data analysis techniques. • Initially focused on manufacturing, but can and has been applied to other industries, including service, healthcare, and education.		

2.1 Categorical benefits of Lean, SS and LSS in healthcare

Lean, SS, and LSS in healthcare have many benefits, such as improvement in FP, OE, PF, P, and C. These benefits will be segmented into categories based on the perspectives of the major stakeholders like customers, shareholders, employees, and regulating body as identified by Donaldson and Preston (1993), which has been more recently employed in the work of Antony et al. (2018).

The cost-reducing benefits of Lean in the NHS were documented in the study of Matthias and

Brown (2016), who examined Lean methods in healthcare outpatient services. Honda et al. (2018) and DelliFraine et al. (2013) have reported total savings of over €1.2 million in the Red Cross Hospital in the Netherlands with SS. Bancroft et al. (2018) produced a study that examined the ability of Lean to reduce patient waiting time in NHS. Similar results have been achieved by Vermeulen et al. (2014), and Furterer (2018). Thus, it is evident from the literature that Lean has proven to reduce patient wait and stay times in health services. Gijo et al. (2013) investigated the use of SS in a pathology department in a specialty hospital attached to a manufacturing company. The DMAIC methodology resulted in an over 50% reduction in patient wait time from 24 minutes to over 11 minutes. Bush et al. (2007), Bertolaccini et al. (2011), Gayed et al. (2013), Niemeijer et al. (2013), and Honda et al. (2018) generated similar findings in their study related to reduction in reduced length of stay. Further, Fischman (2010), Antony and Gijo (2014), and Bhat et al. (2014) focused on the reduction of patient wait times.

There are several studies undertaken, such as Chan (2004), Esimai (2005), Benitez et al. (2007), Rodriguez-Gonzalez et al. (2015), Antony and Trakulsunti (2018), Antony et al. (2019), and Trakulsunti et al. (2020) that reported the reduction in medical errors with the help of Lean and SS methodology. Charlatan (1999) presented how medication errors kill 98,000 people every year in the USA, whilst Donnelly (2018) cites how medication errors cause up to 22,000 deaths every year in the NHS. Since the consequences of medication errors can be fatal and therefore, the ability to reduce such errors is of critical importance. There is a dearth of empirical studies showing that Lean and SS can reduce medication errors, so research is required in this context.

As per the study done by Klevens et al. (2007), 99,0000 medical patients in the US die every year due to hospital-acquired infections and unnecessary medical complications, making it the 6th leading cause of death. To overcome such challenges, the use of the SS process, such as fishbone diagrams, etc., can be utilised to reduce the infection rates (Oakland and Tanner, 2007). Dickson (2013) and Improta et al. (2018) reported the benefits of implementing LSS to reduce surgical site infections by 46% in USA and Italian hospitals across different surgical departments and other medical areas. However, the findings in this study were not conclusive as they lacked reliable supporting data. Interestingly, no studies have yet been undertaken which document the potential of Lean to increase the quality of care. There is limited additional supporting empirical data, and it is clear that more research must be

conducted in this area.

As per the study conducted by Vago et al. (2016), the application of Lean enhanced nurses' working efficiency by reducing their average steps per birth by 81%. According to the study, the turnover time decreased from a median of 41 minutes to 32 minutes, whilst turnaround time decreased from a median of 81.5 minutes to 71 minutes. Therefore, not only patients departure time decrease, but also the interval between surgical treatment decreased, resulting in more procedures being completed per employee shift (Tagge et al., 2017). Similar work has been reported by Bhat et al. (2014) in the Health Information Department (HID) of an Indian medical college. In this regard, more work is required to understand the benefits of applying LSS in achieving operational excellence in terms of resource planning.

The potential of SS to increase patient satisfaction was documented by DuPree et al. (2009), who analysed pain management in two inpatient units within an urban academic medical centre. It was found that overall satisfaction in "pain management" increased excellently with ratings from 37% to 54%. These findings were reinforced in the work of Bush et al. (2007), who also displayed in their study how reduced patient wait times from 3.2 hours to 1.5 hours could improve patient satisfaction scores from 5.75 to 8.54 (on a 10-point scale). Jayasinha (2016) investigated the impact of LSS on patient satisfaction in a pediatric clinic, and overall patient satisfaction increased from 87% to 95%. Thus, LSS has shown how its capability to redesign processes can result in better quality service and enhanced patient satisfaction (Antony et al., 2018; Natale et al., 2014).

Employee engagement can be defined as a person's involvement, satisfaction and enthusiasm for work (Khan, 1990). The Lean and SS approach plays a vital role in enhancing nurses and pharmacists' relationship (Esimai, 2005). Further, it has also helped to drive communication between departments and break down silos. This has motivated employees to engage in cross-functional tasks and cooperate with others (Bucci, 2005). However, there is no empirical evidence to support that LSS can enhance employee engagement. In contrast, Stanton et al. (2014) argued that employee engagement increased after implementing Lean and SS in an Emergency Department (ED) in Australia. However, it was due to the senior staff being able to leverage resources to create favourable outcomes rather than a direct result of LSS. Therefore, a detailed study is required in this regard.

Vanzant-Stern (2010) presented how Lean can be used in global health services to improve compliance, which satisfies quality requirements and helps healthcare providers obtain ISO 9001 certification. Similarly, SS is also used in health services to overcome the multifaceted medical specification barriers non-compliance. The DMAIC process has been used to eliminate the CFFs of hand hygiene compliance (Clark, 2010) that reduced infection rates by 51%, which led to a saving of $276,000 and crucially saved an estimated 2.5 lives. Healthcare Benchmarks and Quality Improvement (2004) also reported that the benefits of adhering to compliance under SS project implementation and surgical incision increased from 19% to 100% in only three months. Hence, more research is required to comprehend the application of LSS in the healthcare sector.

2.2 Tools and techniques

All the tools were reviewed and recognised by George et al. (2005), who described their use in detail in their book. The highly relevant tools applied are brainstorming, benchmarking, process mapping, patient feedback, cause and effect, scatter diagram, hypothesis testing, and tally charts. It is interesting to note that the Failure Mode and Effect Analysis (FMEA) was not regarded as a common or useful tool in the NHS. Rodriguez-Gonzalez et al. (2015) also stated the tremendous potential of theses tool to improve patient safety and reduce medication errors in Spanish hospitals. For evaluating the healthcare systems, the Theory of Constraints (TOC) approach is frequently used (Yu et al., 2021; Chen et al., 2020). In particular, to eliminate the patient flow waste in the hospital's outpatient department, Value stream mapping (VSM) is also applied (Gonzalez et al., 2014).

Furthermore, Antony et al. (2017) developed a systematic literature review of SS in healthcare. In their work, 68 papers were reviewed, and 23 major SS tools were identified. The most competitive ones are data collection strategy, critical to the quality linkage, design of experiments (DoE), cost-effectiveness analysis, statistical process control (SPC), baseline measurement, and voice of customer analysis. Antony et al. (2019) reviewed the application of Lean tools in healthcare around the world. Their work reviewed 101 articles from 88 different journals. The three most effective tools, viz. 5Y analysis, waste analysis, and mistake-proofing adopted in health services.

2.3 Critical Failure Factors (CFFs)

CFFs are the key aspects of an implementation process which if not executed correctly, may

limit or prohibit the success of the project or process altogether (Garg and Garg, 2013; Ganesh and Mehta, 2010). As a result of CFFs, it was reported that around 54% of healthcare companies could not implement the SS strategy properly (Feng and Manuel, 2007). As per the study conducted by Glasgow et al. (2010), it was found that 62% of the initiatives fail due to a lack of stakeholder acceptance. Albliwi et al. (2014) developed the first and largest ever systematic literature review of the CFFs of LSS across different sectors, such as manufacturing, healthcare, higher education and services. Fifty-six papers were analysed, and a total of 36 CFFs were identified.

3. Research Methodology

In this paper, the researchers have adopted the worldview of "positivism" as a scientific perspective because of the objective stance and the deductive research approach (Clark, 1998). This philosophy has steered the selected methodology and the particular tools to obtain primary data based on the corresponding research objectives (O'Gormanan and MacIntosh, 2014).

This paper utilised a survey questionnaire based technique. Flynn et al. (1990) highlight that the questionnaire-based survey approach is the most commonly used alternative in Operation Management research. This is because it can be sent to many organisations at different locations, standardisation of questionnaire allows comparison of responses, a flexible time where respondents can choose their own time, a relatively fast way of collecting data, and respondents can answer based on their knowledge, in the case of open-ended questions (Cooper and Schindler, 2006). The present survey has been confirmatory to gather quantitative data to achieve the highlighted research objectives.

The survey questionnaire is composed of 4 sections, with a total of 10 principal questions. All questions and factors were derived from the extensive literature previously reviewed throughout this paper as presented in Appendix -A. With reference to the previous works conducted by Dombroski and Mielke (2013), Antony et al. (2018), Cheng et. al. (2015), Improta et al., 2018 Antony and Kumar (2012), Antony et al. (2017), Antony et al. (2019), and Albliwi et al. (2014), a list of the top 8 CI methodologies, 18 benefits, 32 tools and techniques and 36 CFFs were produced respectively. Section 1 of the survey questionnaire consisted of 5 multiple choice questions that enabled participants to provide additional written responses detailing whether Lean and SS implementation had changed the NHS's

culture. In sections 2-4, a 5-point Likert Scale (with one being the lowest and five being the highest) were utilised for the tools, benefits and CFFs as presented in Appendix A. Notably, the use of a 5-point Likert Scale successfully supported the aims of this study by ensuring that the questioning and responses were reliable, valid and directly comparable (Bell et al., 2018; Joshi et al., 2015). Specifically, a total of 3 Likert Scales were used to analyse and compare the effectiveness of Lean, SS and LSS to drive improvements across the 18 highlighted benefits. Furthermore, 1 Likert Scale was used to analyse the 32 tools and techniques, and 1 Likert Scale was used to analyse the 36 CFFs.

The survey questionnaire was initially test piloted by 10 participants from the NHS. Based on their feedback, three questions were removed, and two were reworded. The survey was created using Qualtrics software and was emailed and physically distributed to 1,218 people from 12 May 2020 to 19 June 2020. A total of 48 respondents could not complete the study due to never having used Lean or SS in the NHS.

Out of the remaining 1170 people, this survey questionnaire received a response rate of 9.4%, with 110 participants completing it entirely. The average number of survey responses per day was 2.9. Indeed, the response rate can be considered reasonably satisfactory, and it provides a sufficient data set to satisfy the research objectives outlined in this study (Saunders et al., 2010). Figure 1 presents the breakdown of the survey questionnaire respondents. As data were collected at an individual level, inter-reliability, which measures judgements' consistency on a particular survey item, could not be gauged.

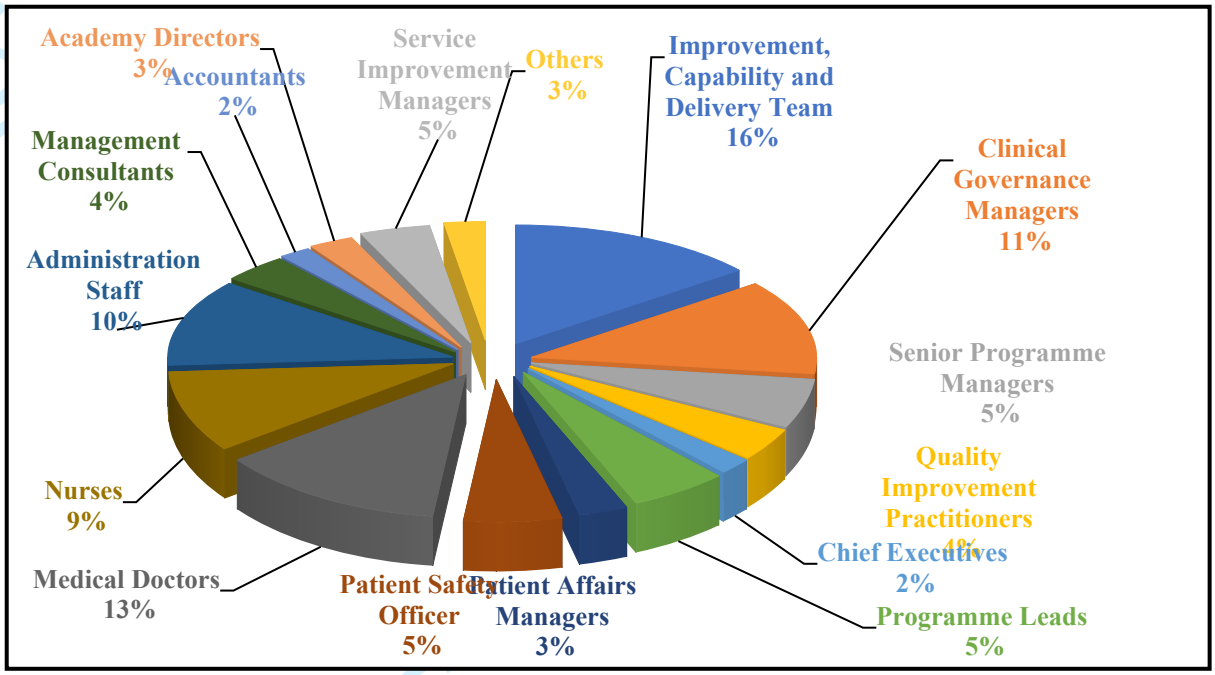

Figure 1: Type of Respondents and Percentage Contribution (110 participants)

4. Results

Firstly, this paper sought to understand the most common types of CI and QI methodologies currently being used throughout the NHS by people who have experience utilising Lean and SS. The study indicated that Lean was the most commonly used methodology, with 72.7% of respondents indicating that they have applied it within the NHS, followed by LSS (54.5%) (Figure 2). This section of the survey showed the low usage rate of SS, with only 26.4% of participants stating that they have applied it in the NHS. It was found that four other methodologies are more commonly used than SS. The least common methodology reported was Rapid Improvement Events (RIE), with a usage rate of only 19.1%.

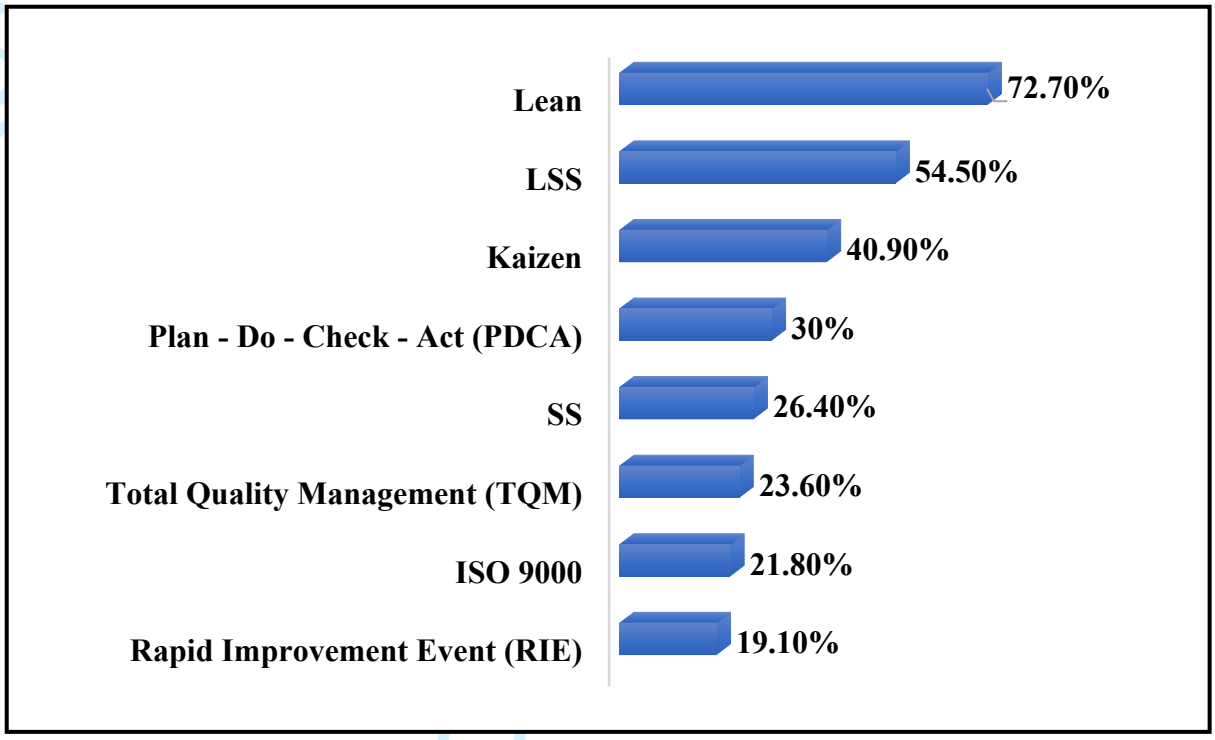

Figure 2: Breakdown of Percentage of Respondents per Methodology

4.1 Comparison of the effectiveness of Lean, SS and LSS

The second objective was to compare the potential of Lean, SS and LSS to drive improvements in the identified five significant categorical benefits (FP, OE, PF, P and C). The results for each methodology have been displayed in Figure 3, 4, and 5.

Out of the 18 total benefits identified in the literature review, the survey found that by comparing the average mean response that Lean was considered moderately effective (scoring three or higher) to produce ten different individual benefits in the NHS. Notably, this signifies that Lean can drive at least moderate benefits in over 55% of all the currently recognised potential benefits of Lean and SS across healthcare services. However, as displayed by Figure 3, it was interesting to note that reducing medication errors and improving patient safety was among the top 5 most effective Lean benefits with scores of 4.55 and 3.91, respectively.

One of the most exciting survey findings was the stark contrast between the FP benefits. While "cost savings" were recognised as a key benefit, it was shown that Lean is not considered an effective methodology in the area of "revenue enhancement". Moreover, as seen in Figure 3, it was apparent that Lean is not accepted by NHS staff as an effective

methodology for enhancing benefits within the P category. All three individual P benefits were ranked amongst the bottom five. Therefore, whilst NHS staff currently believe that Lean helps enhance the majority of recorded potential healthcare benefits, it is not regarded as the cure to solve all of the NHS's problems.

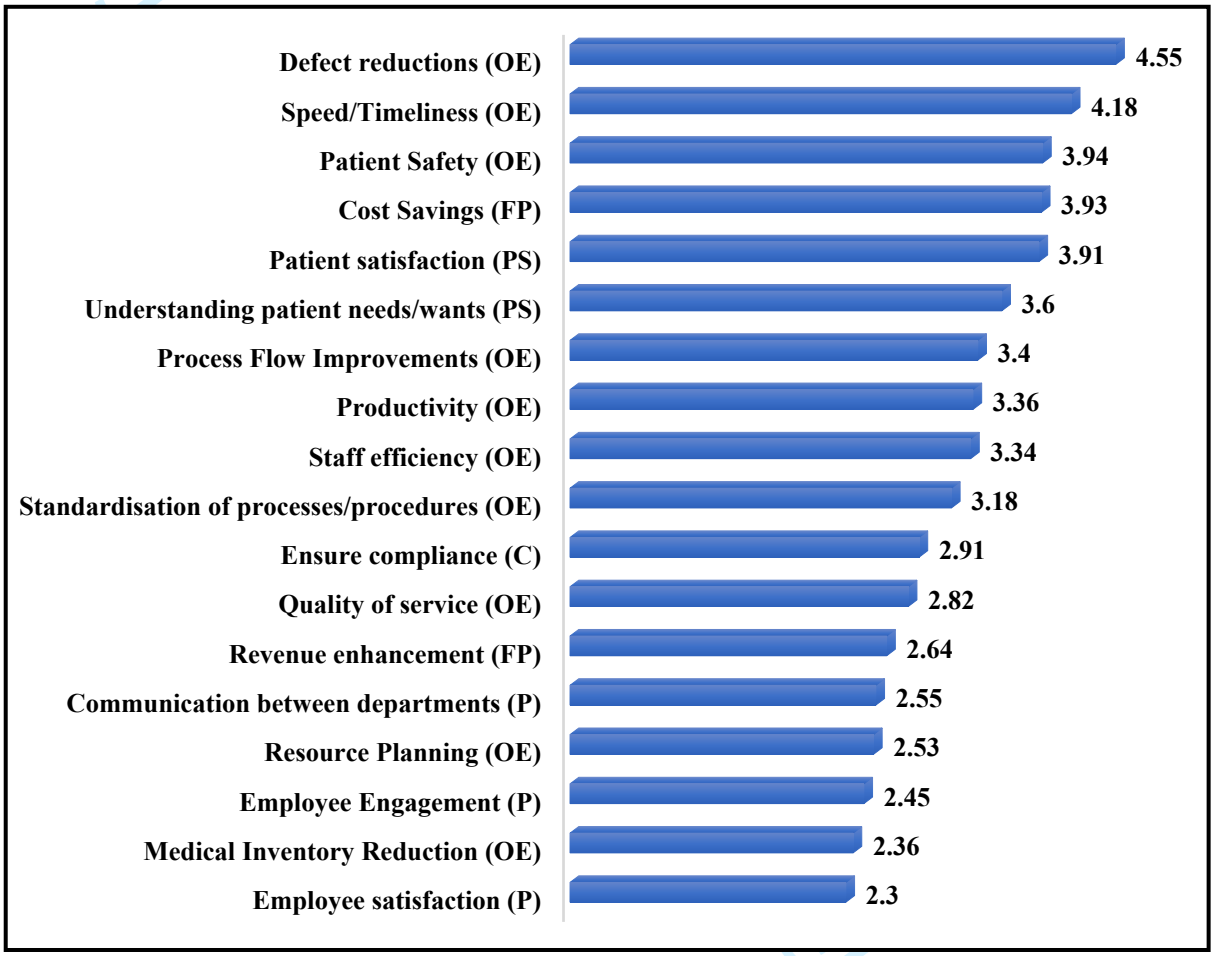

Figure 3: Effectiveness of Lean in the NHS

The survey demonstrated that SS was moderately effective for producing 61.1% or 11 out of 18 individual benefits. Interestingly, it was also found that SS was heavily associated with quality, as "Quality of Service" was selected as the top benefit of SS (Figure 4). However, it was evident that SS was not recognised in the literature as a beneficial tool for reducing costs. There is no credible evidence that cites SS's ability to enhance revenue. Further, it is imperative from the study that SS could be used very effectively to ensure compliance. However, it was also evident that SS is not just effective at improving quality and compliance; it is also a handy methodology for increasing both productivity and efficiency. Therefore, it is now recognised that SS can help the NHS deliver more excellent value to

their patients by offering better, faster, and more effective care whilst simultaneously reducing waste.

On the other hand, the survey unearthed that SS is not very effective at producing individual benefits within the P category. Notably, as seen in Figure 4, the bottom five benefits were made up of benefits classified as part of P. Based on the lack of previous literature, it was to be expected that SS would not be an effective methodology for "Employee Engagement" Employee Satisfaction" and "Communication Between Departments". The literature review portrayed a significant quantity of reliable works reinforced by robust empirical data, which detail healthcare providers' ability to apply SS to increase patient satisfaction and excellency scores. Despite the evidence of the literature, "understanding patient needs" was in the bottom five benefits.

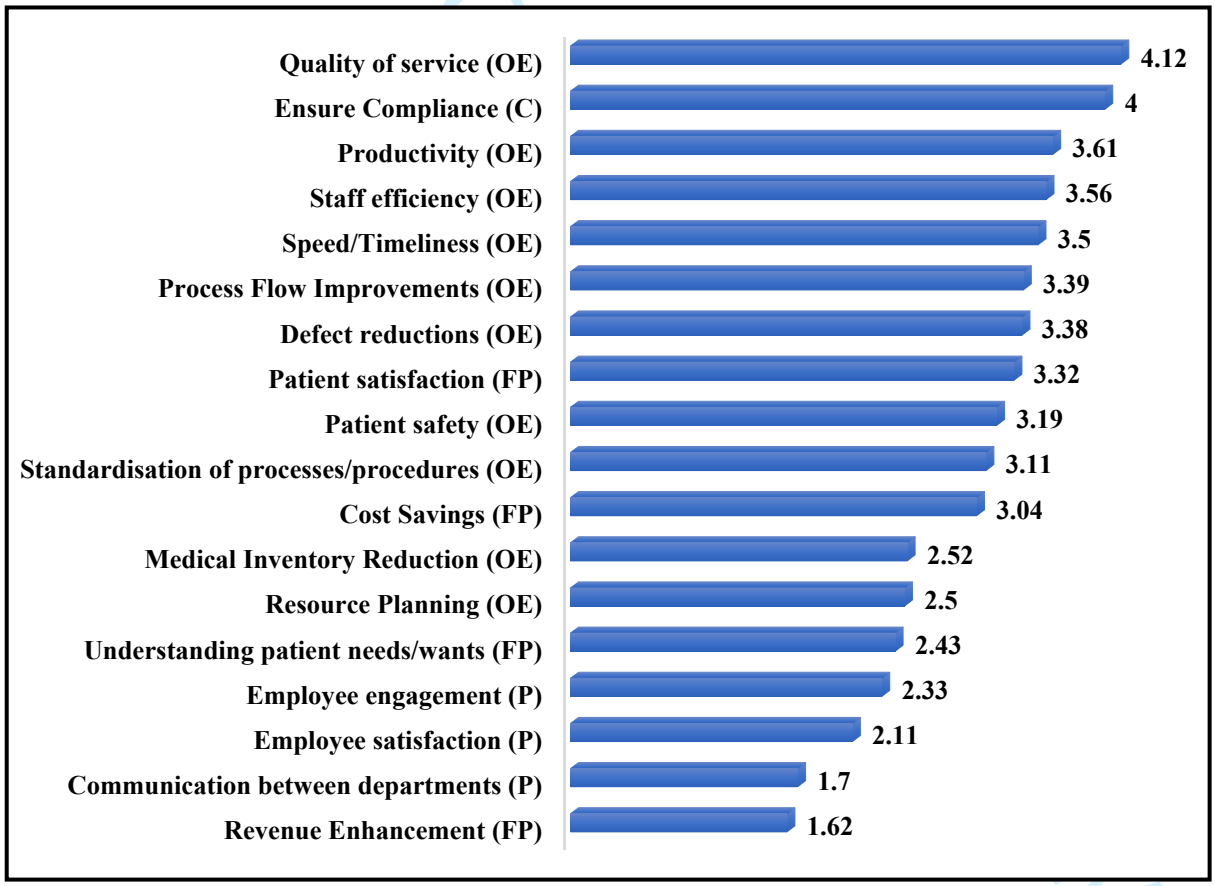

Figure 4: Effectiveness of SS in the NHS

It was reported that 13 out of 18 or 72% of all proclaimed LSS benefits were considered to be at least "moderately effective". These benefits were related to 4 out of the five categories. It

was also revealed that LSS was "very effective" for delivering 7 out of 18 benefits across three categories or 39% of all the total individual benefits listed. However, the only category in which LSS is not currently effective in improving P (Figure 5). Interestingly "Employee Satisfaction", "Communication Between Departments", and "Employee Engagement" were not even considered as "moderately effective", and they were among the bottom 5 with the latter ranked in the lowest position of 18 (Figure 5).

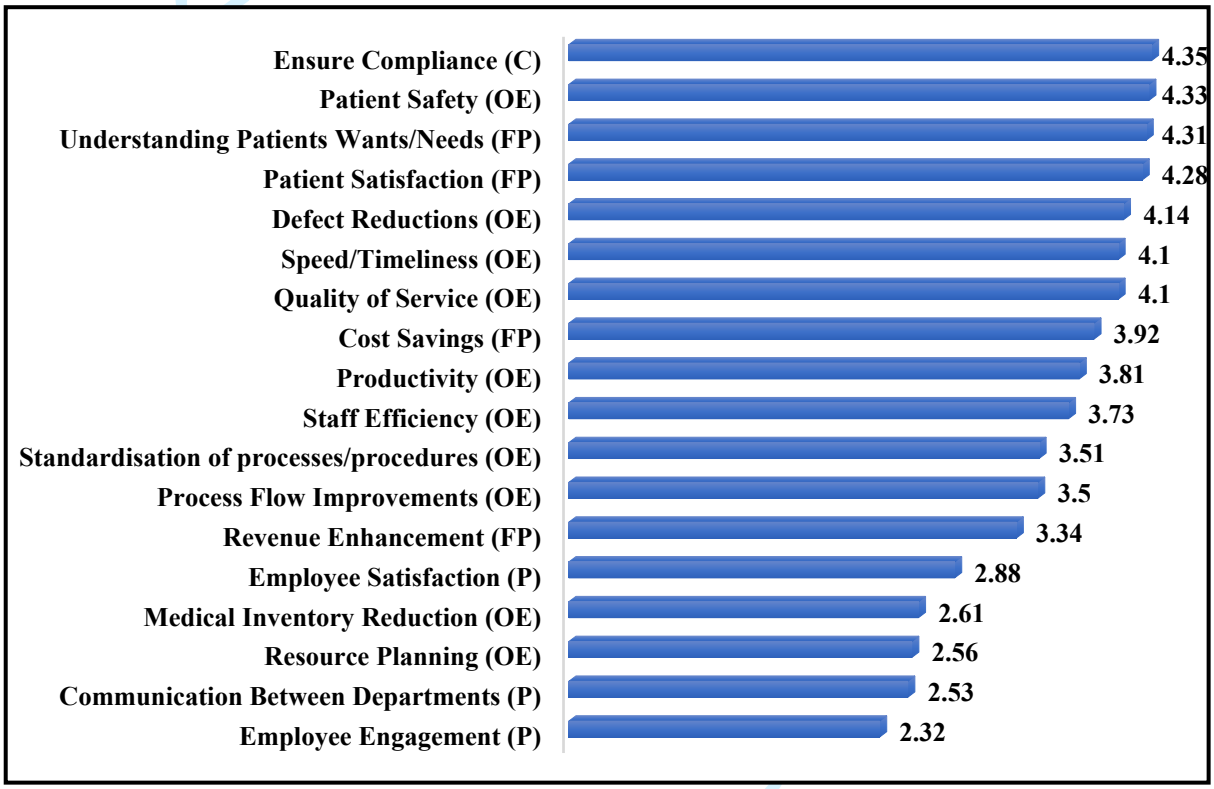

Figure 5: Effectiveness of LSS in the NHS

4.2 Overall comparison of the effectiveness of Lean, SS and LSS

The overall comparison of the effectiveness of each methodology is displayed in Table 2. Firstly, on average, NHS staff consider Lean, SS and LSS to be highly effective methodologies that can be successfully administered throughout a wide variety of areas. All three methodologies received high ratings for the percentage of benefits applied as least moderately effective. However, the survey findings demonstrate that LSS was considerably more effective than Lean and SS for successfully delivering the highest number of total benefits across the NHS. Even more notable was the ability of LSS to be "very effective", with 39% of total benefits receiving a score of at least 4.0, which was significantly higher than the 11% registered by both Lean and SS. SS was cited as the second most effective

methodology as despite being equally capable of producing the number of “very effective” benefits as Lean, SS produced slightly more" “moderately effective” benefits. Therefore, SS and Lean's overall effectiveness are very similar, but LSS is undoubtedly the most effective methodology among the 3. All three methodologies were least effective at delivering benefits related to the P category, and both SS and LSS were most effective at C.

Table 2: Overall Comparison of Effectiveness

Categories	**Lean**	**SS**	**LSS**
Percentage of benefits ranked at least Moderately Effective (3.0 or over)	55%	61%	72%
Percentage of Benefits Ranked at least Very Effective Benefits (4.0 or over)	11%	11%	39%
Most Effective Benefit Category (Mean)	Focusing on Patient	Compliance	Compliance
Least Effective Benefit Category (Mean)	People	People	People
Most Effective Individual Benefit	Defect Reductions	Quality of Service	Ensure Compliance
Least Effective Individual Benefit	Employee Satisfaction	Revenue Enhancement	Employee Engagement

Figure 6 displays each methodology’s overall effectiveness to deliver benefits relating to FP. Interestingly, it was found that LSS was the most powerful methodology for enhancing overall FP and was the only methodology considered to be capable of at least producing “moderately effective” improvements for both “Cost Reduction” and “Revenue Enhancement”. However, in terms of reducing costs, Lean was selected as the most effective methodology with a slightly higher score than LSS of 3.93 compared to 3.92. NHS staff indicated that all three methodologies were “moderately effective” for reducing costs. SS was recognised as the least effective methodology for delivering both benefits and the only methodology marked as less than “moderately effective”.

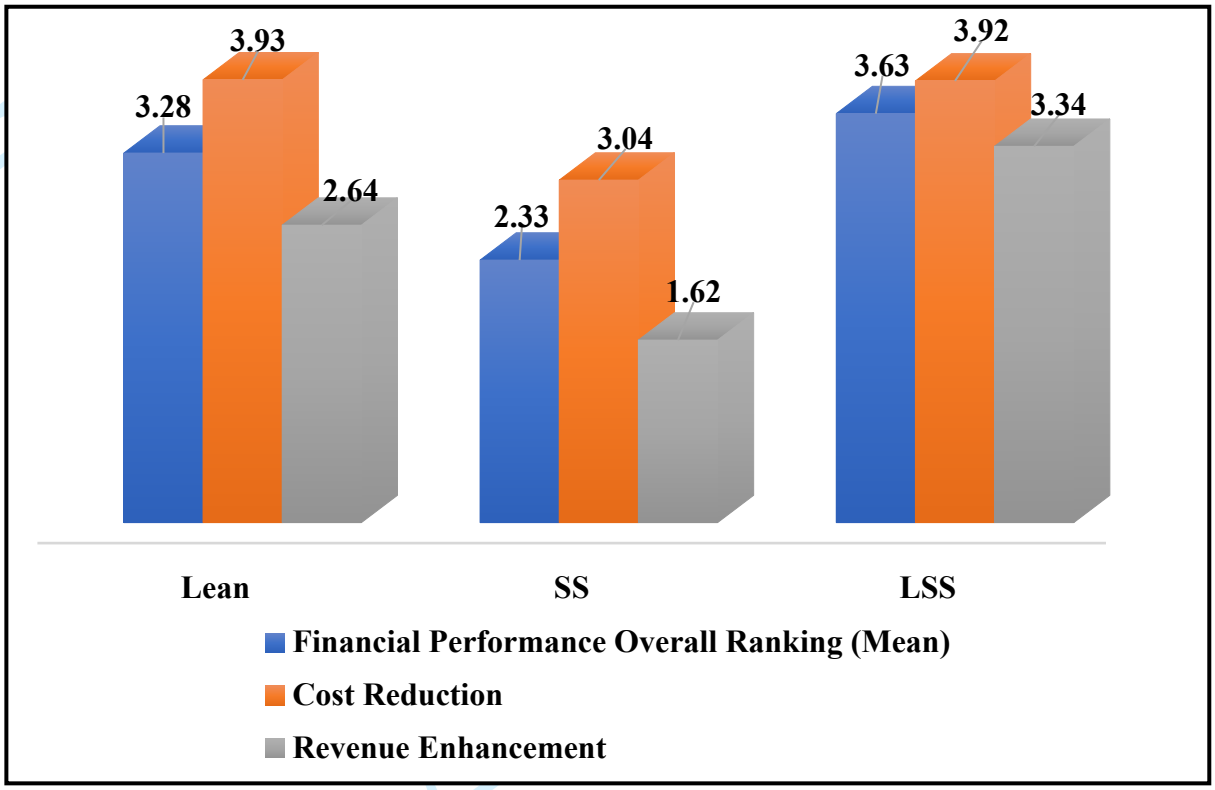

Figure 6: Financial Performance (FP) Comparison

Figure 7 displays each methodology's overall effectiveness to deliver benefits relating to OE. It was evident that despite apparent weaknesses, overall, all three methodologies are considered effective CI tools that can be successfully applied to drive OE to above "moderately effective" standard. Whilst LSS was identified as the overall most effective methodology for delivering operational excellence with a score of 3.64, both Lean and SS received encouraging scores of 3.37 and 3.29, respectively. As benefits relating to OE make up over 55% of the total benefits, the importance of this finding should not be underestimated as it displays the wide-scale capability of all three methodologies. Similarly, many of the highlighted strengths and weaknesses were universal in this category of benefits.

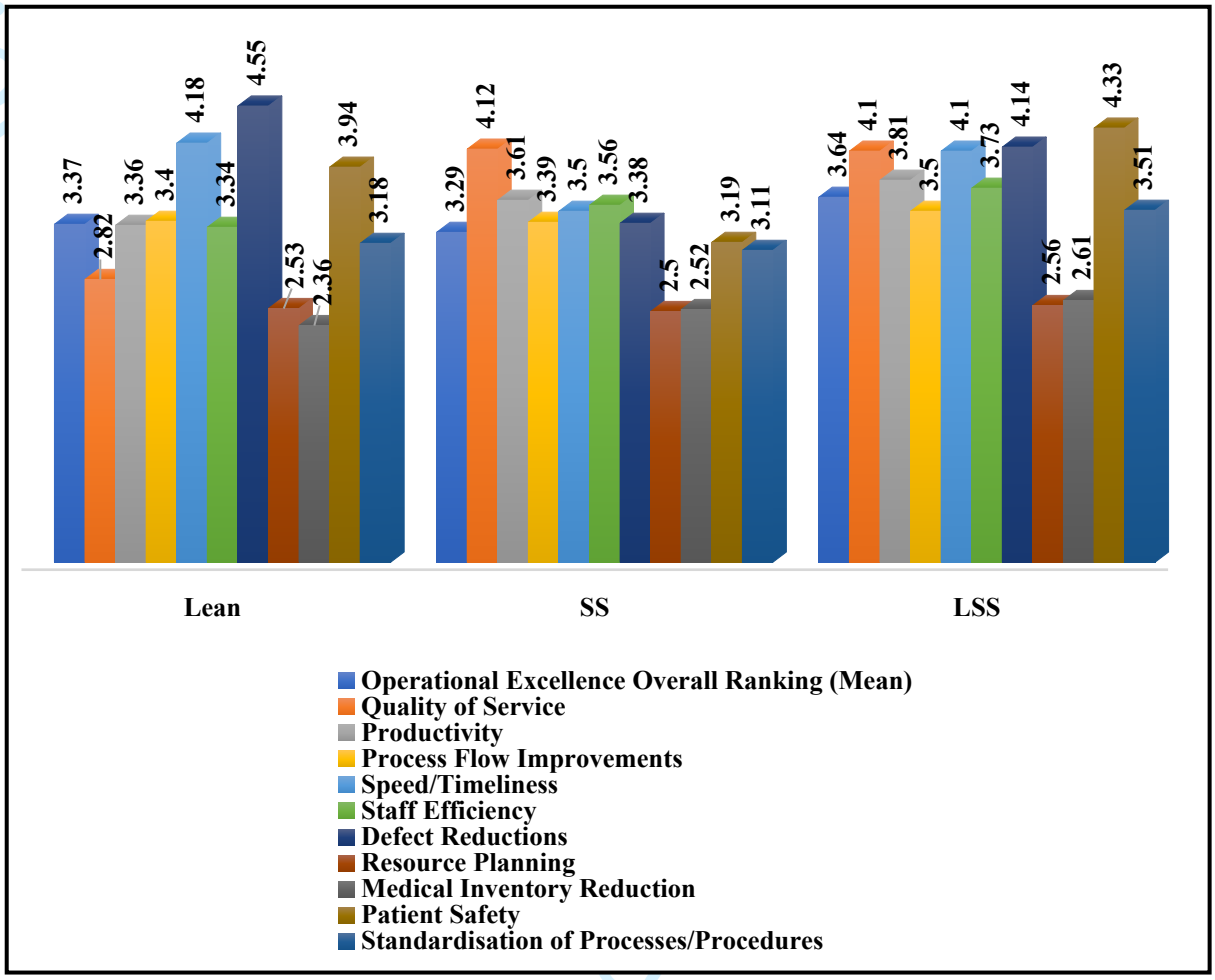

Figure 7: Operational Excellence (OE) Comparison

It was also interesting to observe that all the methodologies received low scores for "Resource Planning", "Medical Inventory Reduction" and were not considered to be even "moderately effective". Out of the ten total benefits that make up OE's category, Lean was the most effective methodology for improving "Speed/Timeliness" and "Defect Reductions". As presented in the literature review, these two benefits are critical due to the potential to save lives and reduce costs. SS was considered the least effective overall for OE and the weakest methodology for delivering a total of six benefits, namely, Process Flow Improvements, Speed/Timeliness, Defect Reductions, Resource Planning, Patient Safety and Standardisation of Processes/Procedures. Thus, despite being ranked as the least effective methodology for six benefits, it is clear that SS was still moderately effective at the vast majority of them. The findings also show that SS was identified as the most effective service quality methodology, reflected in the literature that strongly associates SS with quality.

LSS was not ranked as the least effective methodology for any of the benefits relating to OE

and was also reported to be the most effective for seven benefits: Productivity, Process Flow Improvements, Staff Efficiency, Resource Planning, Medical Inventory Reduction, Patient Safety, and Patient Satisfaction. However, all methodologies have proven to be effective across this sector and must not be disregarded.

Figure 8 displays each methodology's overall effectiveness to deliver benefits relating to PF. This section of the survey results was perhaps the most varied of all the benefits categories, with all methodologies displaying differing overall effectiveness levels. However, it must be noted that despite the low overall score, SS was indeed an effective methodology for increasing "Patient Satisfaction" but admittedly was still ranked as the least effective methodology for this individual benefit. The results illustrate that Lean was the second most effective methodology for both individual benefits and was particularly effective at driving "Patient Satisfaction" with a notable score of 3.90. The only methodology to be ranked as "very effective" was LSS which scored consistently well across individual benefits. This differs from the other methodologies, which were both considerably more effective at "Patient Satisfaction" that "Understanding Patients Wants/Needs". Therefore, the analysis of the findings conducted in this paragraph offers an alternative perspective that challenges previous findings.

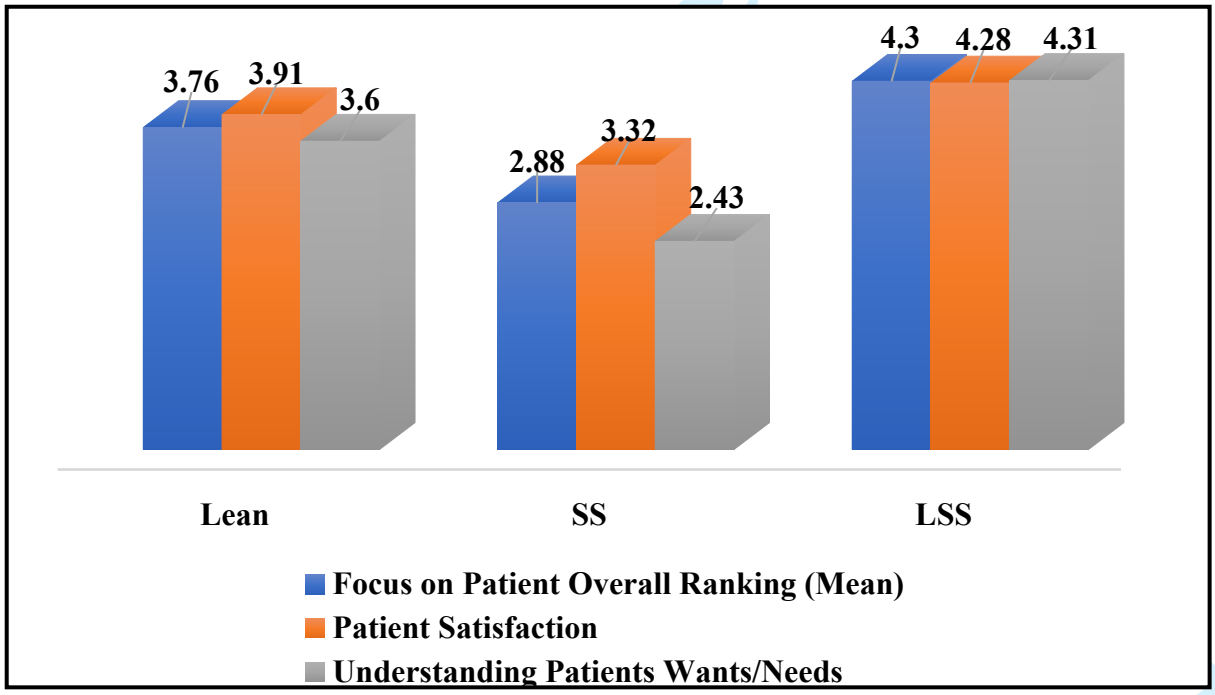

Figure 8: Comparison of Patient Focus (PF)

Figure 9 exhibits the overall effectiveness of each methodology's ability to deliver benefits relating to C. Both SS and LSS are "very effective" in ensuring compliance standards, with the latter being the most effective overall. NHS staff do not recognise Lean as a valuable methodology for "Compliance", and it was not even considered to be "Moderately Effective".

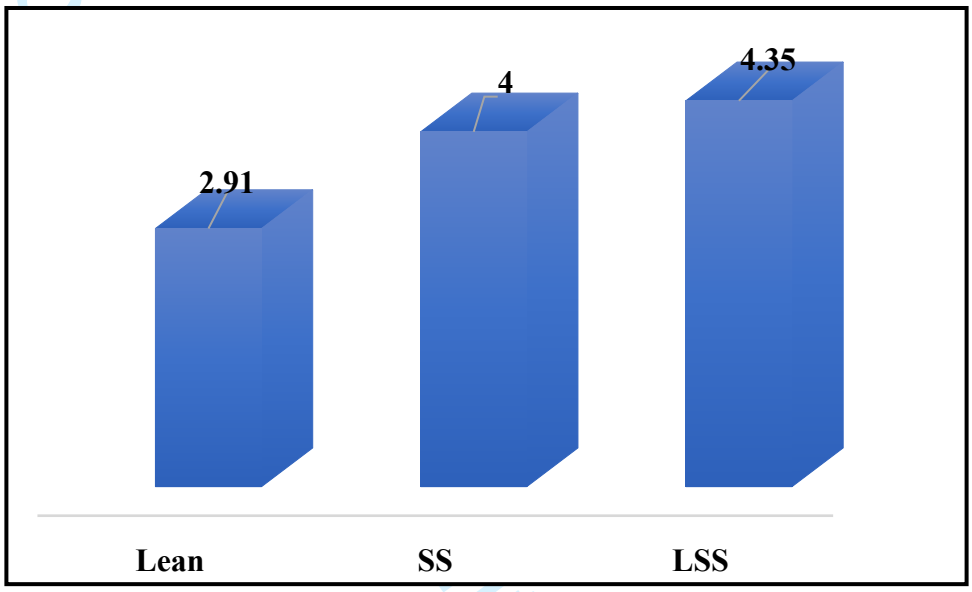

Figure 9: Compliance (C) Comparison

Figure 10 exhibits each methodology's overall effectiveness to deliver benefits relating to P. The analysis of each methodology's effectiveness showed that P was the category that all the methodologies that were least effective. In this sense, the findings show that LSS was the least ineffective methodology for the P category. However, despite this, Lean was less ineffective than both methodologies for two out the three individual benefits. It was evident that SS was the least effective methodology for the P category, and it was awarded the lowest score for every individual benefit.

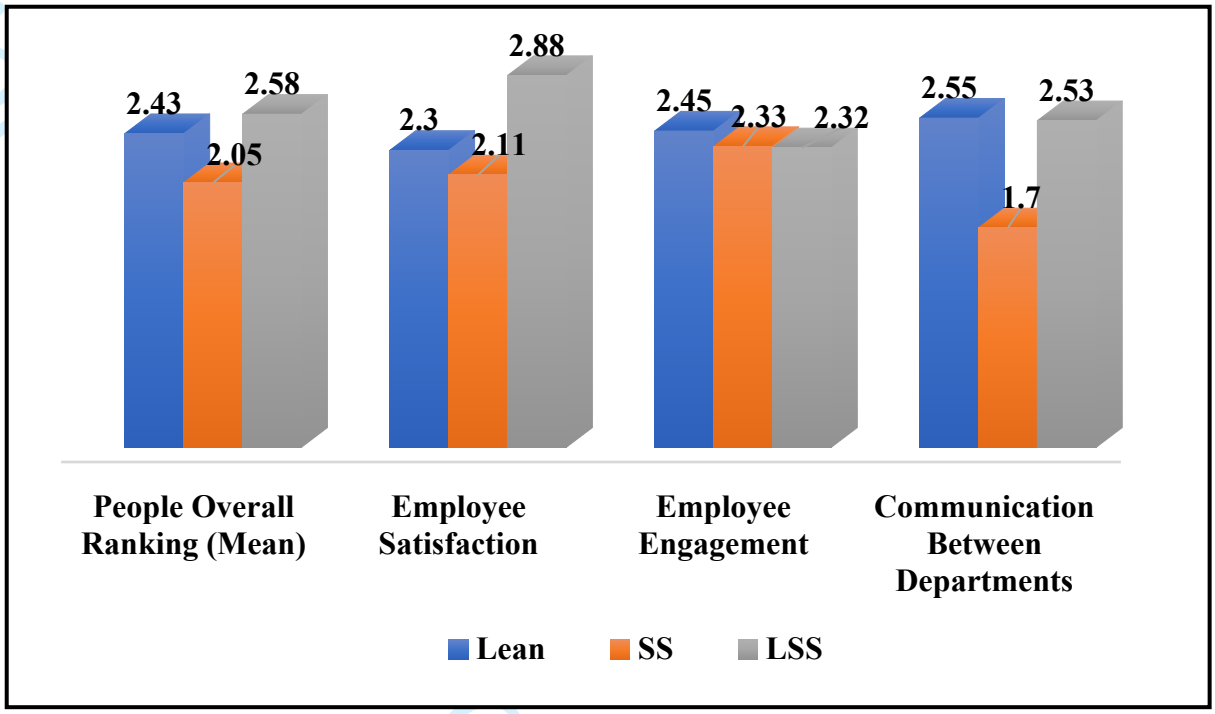

Figure 10: People (P) Comparison

Table 3 and 4 provides the one-way ANOVA results of statistically significant and non-significant variables of effectiveness of Lean, SS, and LSS in NHS. From the Table 3 it can be seen that overall effectiveness of Lean, SS, and LSS in NHS is statistically significant ($p < 0.05$). Moreover, from the Box Plot (Figure 11) it can be concluded that effectiveness of LSS more compared to its counter parts. Further, table 5 displays a summary of the findings of the overall effectiveness comparison of all three methodologies across the five performance categories. Eventually, from this analysis it can be culminated that adoption of LSS has helped in driving improvements throughout each of the five categorical benefits - Financial Performance (FP), Operational Excellence (OE), Patient Focus (PF), People (P), and Compliance (C) across the NHS.

Table 3: Statistically significant variables from One-way ANOVA

SI. No.	Variables	P-Value
1	Overall Effectiveness	0.045
2	People Focus	0.002
3	People	0.016

Table 4: Statistically non-significant variables from One-way ANOVA

SI. No.	Variables	P-Value
1	Financial Performance	0.077
2	Operational Excellence	0.342
3	Compliance	-

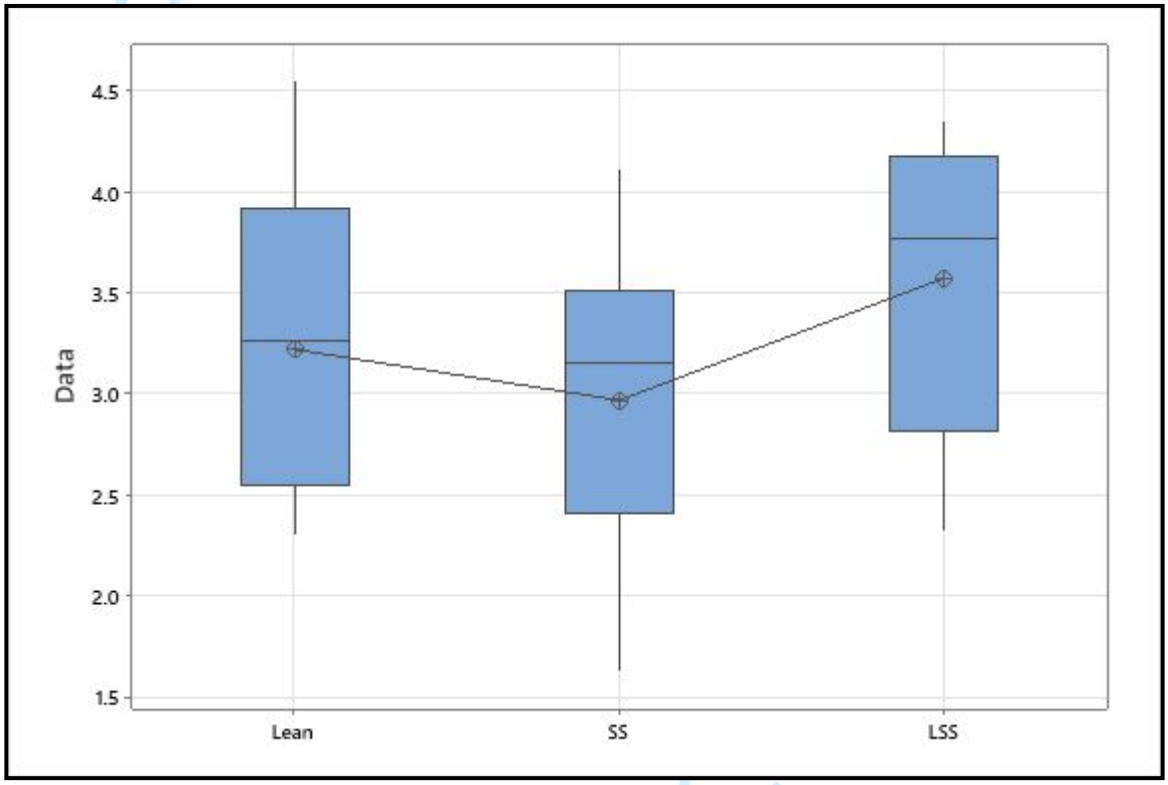

Figure 11: Box Plot of Overall Effectiveness of Lean, SS and LSS

Table 5: Overall Effectiveness Summary

Categorial Benefit	Most Effective Methodology	Least Effective Methodology
Financial Performance (FP)	LSS	SS
Operational Excellence (OE)	LSS	SS
Patient Focus (PF)	LSS	SS
People (P)	LSS	SS
Compliance (C)	LSS	Lean

4.3 Tools and Techniques

Thirdly, in total, the literature review identified 32 tools and techniques from the work of Antony and Kumar (2012) and an additional ten tools and techniques were derived from the following academic literature. Figure 12 presents the top 16 most commonly used tools and techniques. There were significant contradictions between this survey questionnaire results, and the findings produced eight years ago by Antony and Kumar (2012). For instance, it was found that many of the lowest-rated tools and techniques in the work of Antony and Kumar (2012) are now identified by NHS staff to be common practices.

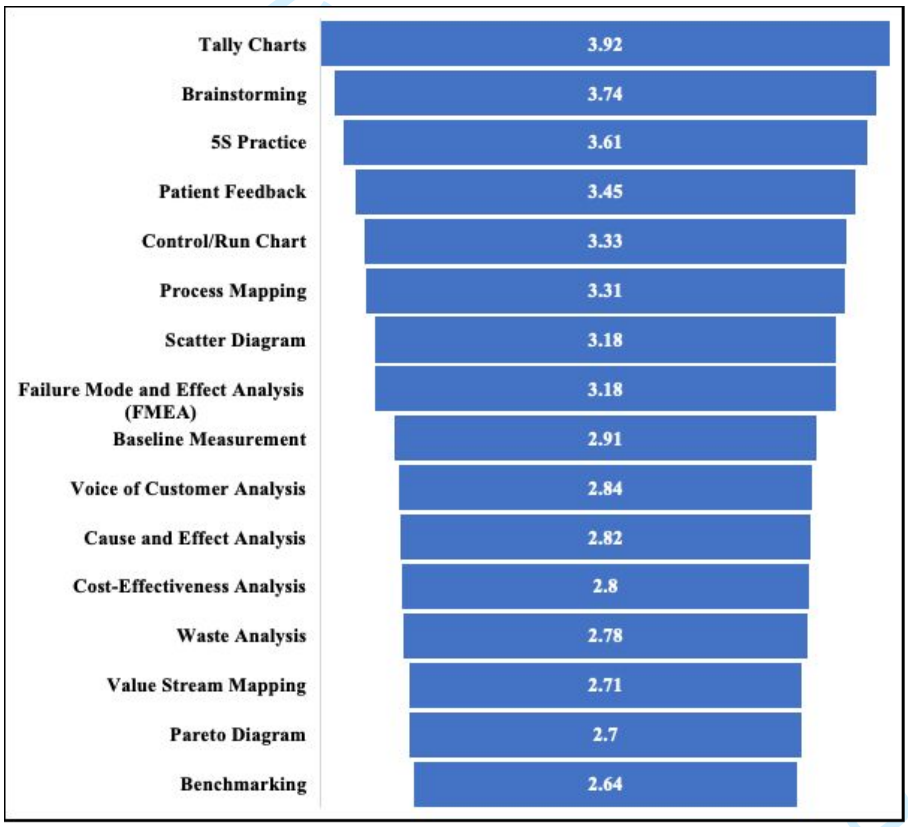

Figure 12: Top 16 Used Tools and Techniques

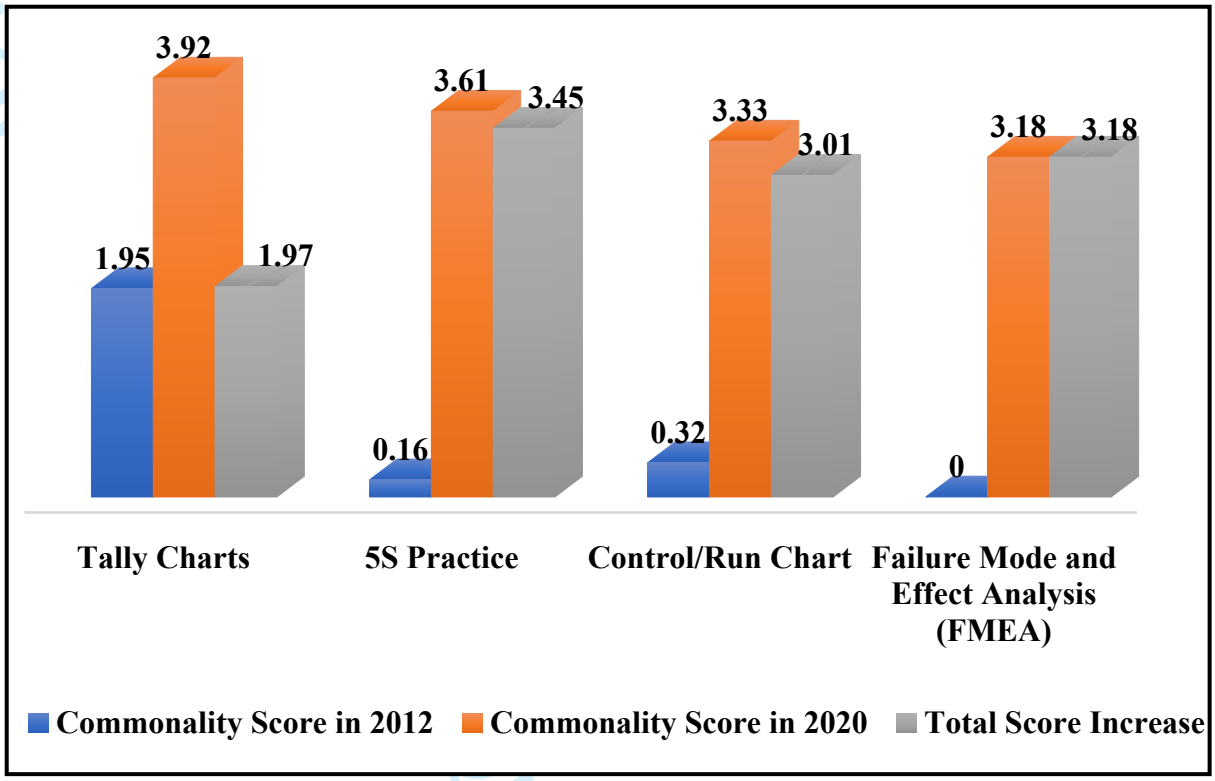

Figure 13: Tools and Techniques Commonality Changes

Furthermore, it was found that a total of 8 tools and techniques were ranked as "commonly used" (Tally Charts, Brainstorming, 5S Practice, Patient Feedback, Control/Run Chart, Process Mapping, Scatter Diagram, FMEA). This reflects how the NHS now has an extensive list of well-established Lean and SS commonly applied tools and techniques. However, no tools were reported as "very regularly used", with no tool receiving a score of over 4.0. None of the tools or techniques, ranging from error proofing, SIPOC and a wide range of statistical tools, were used "commonly" by the NHS. A total of 14 of the tools and techniques were given a score of over 2.0, signifying that they are at least rarely used. Moreover, it was found that 4 of the lowest rated tools and techniques in the work of Antony and Kumar (2012) namely 'Tally Chart', '5S Practice', 'Control/Run Chart', and 'Failure Mode and Effect Analysis (FMEA)' are now identified by NHS staff to be common practices (refer Figure 13).

4.4 CFFs

A total of 36 CFFs that were derived from previous literature were evaluated in the survey questionnaire. Figure 14 displays the mean importance for each CFFs. A highly significant finding of this section was that there are a sizable array of important CFFs for the NHS to consider. It was found that 69.4% or 25 out of the total 36 CFFs were rated as least 3.0 or

higher, signifying that they are considered "important" by NHS staff. Additionally, it was interesting to observe the distinguished importance of the top 5 CFFs displayed in Figure 14.

Notably, 4 out of the top 5 CFFs were perceived as "very important" with at least 4.0. The only CFF in the top 5 which did not receive a "very important" rating was "Resistance of Culture Change", which still received a prominent mark of 3.90. Thus, the results portrayed in this section of the survey questionnaire reflect that it can be tremendously difficult for the NHS to apply Lean or SS successfully.

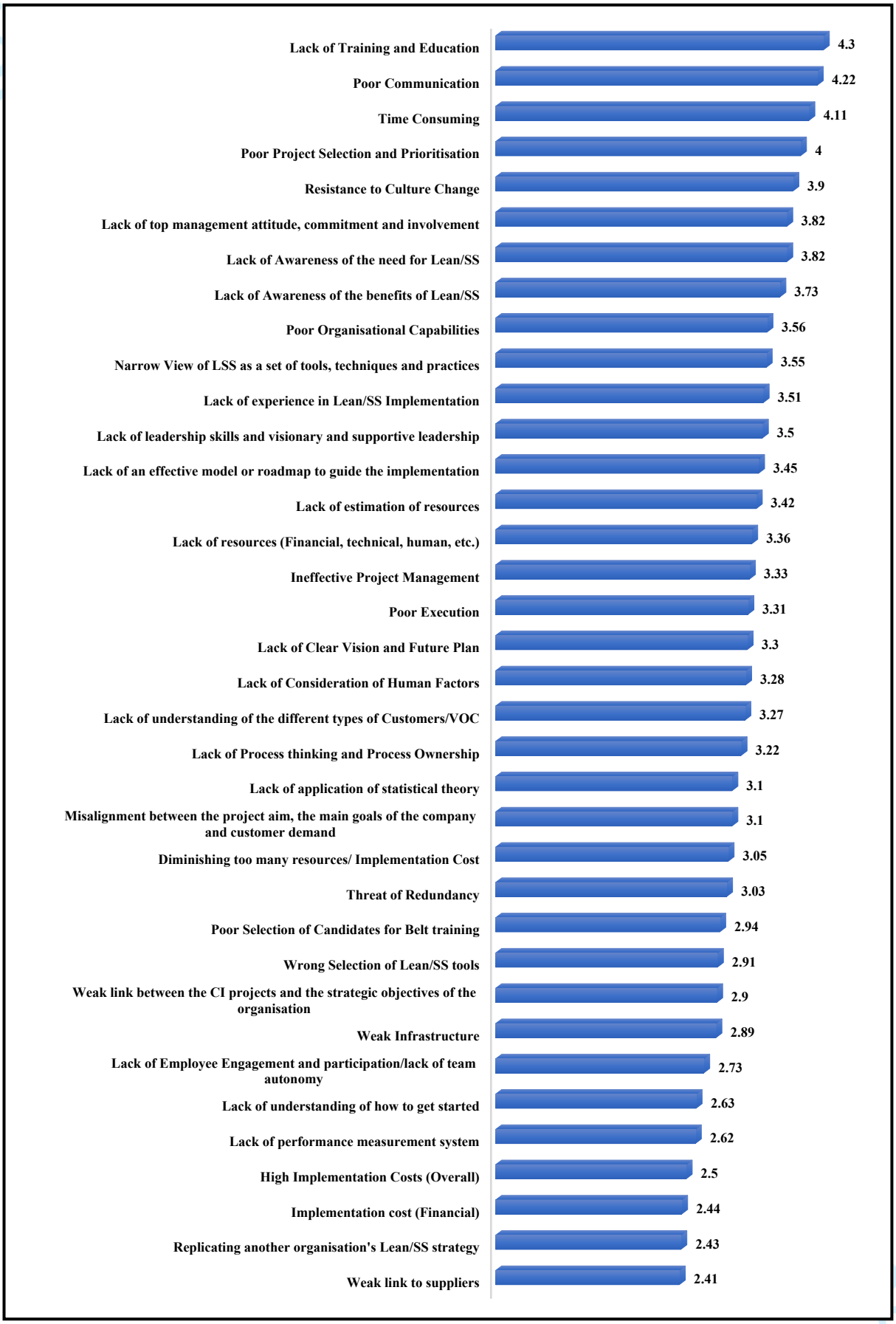

Figure 14: Overall Importance of CFFs

4.5 NHS Culture Change

"Culture" was identified in the literature to be an essential component of Lean and SS. Figure 15 displays the breakdown of the findings. Whilst "No" received the highest number of votes (46%), it is not a majority and certainly cannot be considered conclusive. Around 32% of all participants selected "Yes", signifying that Lean and SS application has, in their opinion, changed the culture of the NHS. However, a significant 22% of participants were undecided and selected "Maybe", which was enough to tilt the balance of power towards "Yes" or "No". Notably, half of the total number of written responses detailed that they believed Lean, or SS, had changed the NHS's culture on some level. However, it was believed that these cultural changes only occurred in isolated areas or departments, and they were not comprehensive throughout the NHS.

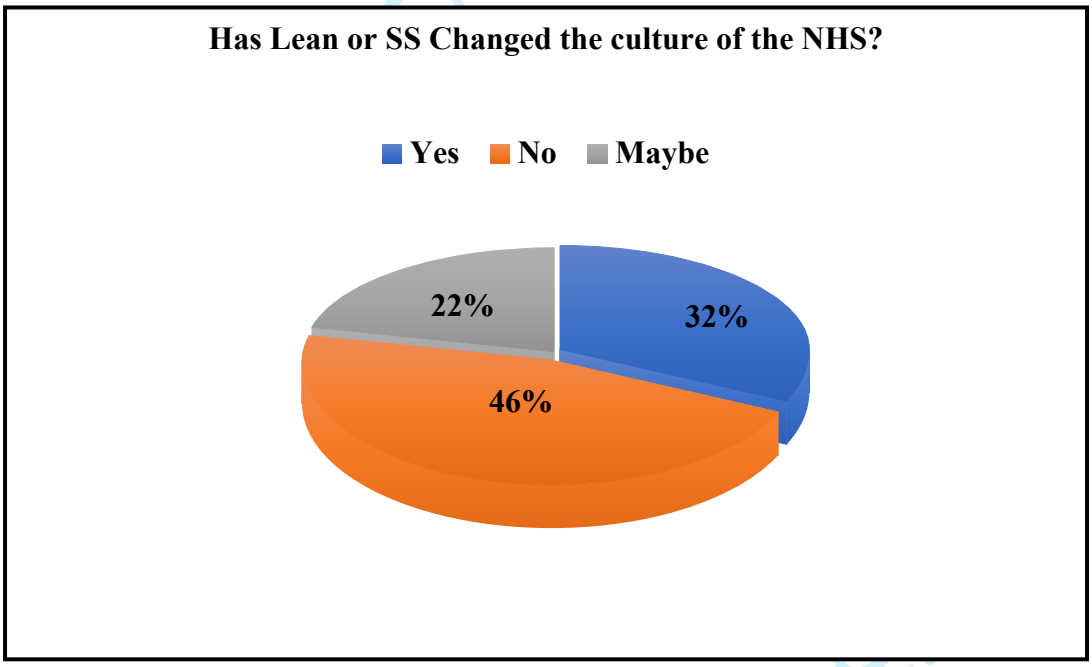

Figure 15: Culture Change

5. Discussion

5.1 NHS Application of CI and QI Methodologies

NHS professionals identified a total of 8 CI and QI methodologies that have been applied in the NHS by an appreciable proportion of staff, as displayed in Figure 2. This contrasts the previous works of Schweikhart, and Dembe (2009) and Improta et al. (2015), who argued that health services did not value CI methodologies and, as such, were not prepared to invest

significant resources into their implementation. Further, it is ascertained that Lean is used by a much more significant NHS staff proportion than LSS or SS. In contrast, the relative lack of SS application was a surprising result. More academic works reviewed SS's potential in health services than Lean (Honda et al., 2018; Tanner et al., 2007). Nevertheless, putting the results into perspective, this paper shows that all three methodologies influence the NHS. Based on the results, Lean and SS have evolved into established methodologies widely used by the NHS.

5.2 The effectiveness of Lean, SS and LSS in the NHS

Firstly, it was uncovered that Lean, SS and LSS are all strongly considered to be both extremely useful and highly effective for initiating improvements "very effectively" in the NHS. Most notably, it was evident that all three methodologies could deliver the majority of the potential benefits to at least a "moderately effective" standard. Indeed, these findings reinforce the works of Antony et al. (2018) and Antony and Kumar (2012), which displayed how Lean and SS have been used to facilitate a varied spectrum of improvements in the NHS and across other health services. Thus, NHS directors who view these findings can be confident that using any of these three methodologies in their services will most likely improve their operations and overall level of patient service.

Moreover, the study unearthed that LSS was recognised as the most vital methodology for administering improvements in each of the five categories of benefits available to the NHS, which responded with the literature (Honda et al., 2018; Trakulsunti et al., 2020; Antony and Trakulsunti, 2018). In particular, in contrast to this paper's findings, there was more previous evidence illustrating the ability of SS than LSS to simulate enhancements for the categories of PF and C (Clark, 2010; Antony et al., 2018). Therefore, it can be determined that the findings of this research objective are similar, yet not comprehensively consistent with the preceding literature. Also, the study observed that LSS was not the most commonly used methodology in the NHS. Lean is being prioritised in the NHS. To provide the highest overall quality of service to their patients, there is strong evidence to suggest that the NHS must change how they view CI and adopt a higher level of LSS usage.

Finally, it was significant to note that there are considerable similarities between all three methodologies' strengths and weaknesses. Notably, it was fascinating to observe that all three methodologies were least effective at delivering benefits to "People". The literature review

revealed this was an area of contention with no clear consensus (Stanton et al., 2014), who argued there was no conclusive evidence that Lean or SS were effective methodologies for driving improvements in this area. Thus, perhaps these methodologies may be applied more effectively, which would allow the NHS to enjoy additional service level augmentations.

5.3 The Commonality of Tools and Techniques

One of the significant findings in the investigation of this research objective was that NHS staff believe a clear and established list of 8 tools and techniques commonly used in their everyday operations. Indeed, this further disproves the works of Schweikhart and Dembe (2009) and Improta et al. (2015) and demonstrates that the application of Lean and SS is now common practice within the NHS as there is a significant list of frequently utilised tools and techniques which staff use on an everyday basis. This knowledge may be of great significance, allowing NHS QI Teams to tailor their operations and services towards tools that most NHS staff are familiar with.

Tools and techniques which were previously found by Antony and Kumar (2012) to be very uncommon are now frequently deployed. As shown in Figure 13, it was found that 4 of the lowest rated tools and techniques in the work of Antony and Kumar (2012) namely 'Tally Chart', '5S Practice', 'Control/Run Chart', and 'Failure Mode and Effect Analysis (FMEA)' are now identified by NHS staff to be common practices. Thus, this may reflect how the current tools and techniques used have developed due to the evolution of Lean and Six Sigma in the NHS. Additionally, 4 of the top 16 tools and techniques (Baseline Measurement, Voice of Customer Analysis, Cost Effectiveness Analysis, and Waste Analysis) were derived from updated literature and were not present in the investigation conducted by Antony and Kumar (2012). However, it must be noted that at this stage, none of the newly investigated tools and techniques is "commonly used". Thus, academics and NHS professionals can use these results to gauge Lean and SS evolution, which can be reinvestigated in the future.

Furthermore, the investigation determined that only two tools or techniques were not even reported as being "rarely used" by NHS staff ("Mistake Proofing" and "QFD"). The findings may serve as a point of reference for introducing new tools and techniques or as a catalyst to initiate educational workshops or programmes explaining how these tools and techniques are applied.

5.4 CFFs

From the study, a total of 25 separate CFFs were reported to be at least "important" by NHS professionals. Previous works such as Ganesh and Mehta (2010) and Albliwi et al. (2014) have developed lists of CFFs for Lean and SS in healthcare. Their studies did not quantify or compare the importance of each CFF. Therefore, whilst no new CFFs have been identified in this paper, the findings presented for this research objective are arguably the most important of the entire study as they have produced new empirical research. In doing so, this new data has illustrated the tremendous level of difficulty for both initiating and maintaining successful Lean and SS implementation in the NHS. Critically, the importance of this finding must not be underestimated as without reliable data. The NHS was unable to navigate through potential implementation barriers effectively. Thus, the NHS can use this information to overcome potential CFFs, which may have been previously overlooked.

5.5 NHS Culture Change

One of the most significant findings uncovered in this paper was the considerable doubts surrounding whether Lean or SS has changed the NHS's culture. Previously, many studies have identified "resistance to culture change" or "incompatible culture" as CFFs which could prohibit Lean and SS in healthcare (Ganesh & Mehta, 2010; Albliwi et al., 2014). However, no previous study has ever investigated whether Lean or SS has changed the NHS's culture. The results display no consensus either way that culture change in the NHS has occurred because of Lean or SS implementation. Thus, this underlines the NHS's need to ingrain Lean and SS into every department's culture. However, it also reflects that the NHS needs to review its operations and develop a more integrated working system.

Finally, NHS staff perceive that there are currently cultural barriers separating junior employees from senior management. Notably, other previous works such as Antony and Trakulsunti (2018) and Anthony and Kumar (2012) have documented how good team dynamics and senior management involvement in healthcare are fundamental for establishing a culture change that supports CI. Significantly, as "Resistance of Culture Change" was identified as a top 5 CFF in this paper, the NHS must investigate why such notable differences exist between departments and what drives these contrasts. If cultural differences between departments and staff are not resolved, Lean and SS will be almost guaranteed to fail (Antony and Trakulsunti, 2018). Any potential benefits will be lost, and the NHS will be forced to seek alternative methods of combating the series of problems they are currently

facing. Thus, it is vitally important that future research seeks to understand further these complications and how to eradicate them.

6. Conclusion and Agenda for Future Research

Firstly, this paper found that NHS professionals identified eight CI and QI methodologies commonly applied within the NHS. Thus, this reflects that continuous improvement is now an established aspect of the NHS's strategy and operations. Secondly, this paper determined that NHS professionals considered LSS to be the most effective methodology for delivering benefits across all five improvement categories. Lean was still regarded as effective; it could not produce a wide range of improvements to the same standard as LSS. The inability of each methodology to increase employee satisfaction, motivation and communication suggest that NHS professionals must change how these methodologies are being applied or seek alternative strategies altogether.

Thirdly, it was found that there are currently eight common Lean and SS tools and techniques used by NHS staff daily. Only two tools or techniques were not even "rarely used", which demonstrates that there are at least 30 tools and techniques used in some capacity in the NHS. Interestingly, the findings produced in this study were quite different to the results found by Anthony and Kumar (2012), which may reflect the considerable evolution of Lean and SS in the NHS over the past eight years. Fourthly, this paper sought to determine the importance of a total of 36 CFFs of Lean and SS, which were derived from previous literature. In total, 25 individual CFFs were identified as being as least "important", capable of limiting or preventing successful Lean and SS application across the NHS. Indeed, these findings highlight the enormous difficulty of successfully implementing and sustaining Lean and SS in the NHS, which NHS management need to be aware of.

Finally, it was uncovered that Lean and SS had changed some departments' culture, but these cultural changes were not universally present across the entire organisation. All three methodologies (Lean, SS and LSS) are now considered influential CI philosophies that have evolved into common practices within the NHS with an established list of tools and techniques. However, to obtain these benefits, the NHS must overcome a sizeable number of highly important CFFs and divided organisational cultures.

The findings produced in this paper will assist NHS medical directors and practitioners in

obtaining an up-to-date insight into Lean and SS's status in the NHS. The paper will also guide the NHS to critically evaluate their current CI strategy to ensure long term sustainability and deliver improved levels of service to patients. From a theoretical viewpoint this article will add to the empirical studies available on the NHS and on LSS in Healthcare applications in the literature and guide future studies.

The study is limited because it adopted confirmatory research and inference is drawn based on the limited sample size. Also, the study presented here was restricted to the objective of studying the impact of Lean, SS, LSS Strategy on the workflow and resource consumption of the NHS process only. Future research could be conducted by increasing the sample size and segregating the results based on individual departments. This may allow researchers to understand the extent to which the impact of Lean and SS varies between different NHS sectors. In order to determine why any potential differences may exist, it may be advisable for future works to develop detailed frequency diagrams and employ a series of interviews with a range of NHS professionals. Also more research needs to be carried into the reasons for the authors findings that LSS has not changed culture in the NHS

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Appendix-A

Construct Operationalization and Survey Questionnaire

Q. No.	Constructs	Measures/Items	References/Sources
1.	Do you have any experience applying Continuous Improvement (CI) or Quality Management methodologies either within or alongside the NHS? (Options: Yes; No; May be)	Basic Information	-
2.	What is or was your role within the NHS?		
3.	What department are or were you involved in?		
4.	Has Lean or Six Sigma changed the culture of the NHS? (Options: Yes; No; May be)	Organizational Impact	-
5.	Which of the following methodologies and systems have you worked with or applied in the NHS?	• Lean • LSS • Kaizen • Plan-Do-Check-Act (PDCA) • SS • Total Quality Management (TQM) • ISO 9000 • Rapid Improvement Event (RIE)	Yu et al., 2021; Buttigiet et al., 2016; Taylor et al., 2014;; Dombroski and Mielke, 2013; Culcuoglu et al., 2012; Antony and Kumar, 2012; Barney, 2002
6.	How effective is Lean for delivering the following	• Defect reductions • Speed/Timeliness	Antony et al. 2018; Honda et al., 2018;

Q. No.	Constructs	Measures/Items	References/Sources
	benefits in the NHS?	• Patient Safety • Cost Savings • Patient satisfaction • Understanding patient needs/wants • Process Flow Improvements • Productivity • Staff efficiency • Standardisation of processes/procedures • Ensure compliance • Quality of service • Revenue enhancement • Communication between departments • Resource Planning • Employee Engagement • Medical Inventory Reduction • Employee satisfaction	Furterer, 2018; Matthias and Brown, 2016; Vermeulen et al. 2014; DelliFraine et al. 2013; Gijo et al., 2013
7.	How effective is Six Sigma for delivering the following benefits in the NHS?	• Quality of service • Ensure Compliance • Productivity • Staff efficiency • Speed/Timeliness • Process Flow Improvements • Defect reductions • Patient satisfaction • Patient safety • Standardisation of processes/procedures	Improta et al., 2018; Vago et al., 2016; Stanton et al. 2014; Dickson, 2013 Esimai, 2005

Q. No.	Constructs	Measures/Items	References/Sources
		• Cost Savings • Medical Inventory Reduction • Resource Planning • Understanding patient needs/wants • Employee engagement • Employee satisfaction • Communication between departments • Revenue Enhancement	
8.	How effective is Lean Six Sigma for delivering the following benefits in the NHS?	• Ensure Compliance • Patient Safety • Understanding Patients • wants/Needs • Patient Satisfaction • Defect Reductions • Quality of Service • Speed/Timeliness • Cost Savings • Productivity • Staff Efficiency • Standardisation of • Processes/procedures • Process Flow Improvements • Revenue Enhancement • Employee Satisfaction • Medical Inventory Reduction • Resource Planning • Communication Between Departments	Antony et al., 2018; Natale et al., 2014; Jayasinha, 2016; 2014; Stanton et al. 2014

Q. No.	Constructs	Measures/Items	References/Sources
		• Employee Engagement	
9.	How commonly is each of the following tools and techniques applied within the NHS?	• Tally Charts • Brainstorming • 5S Practice • Patient Feedback • Control/Run Chart • Process Mapping • Scatter Diagram • Failure Mode and Effect Analysis (FMEA) • Baseline Measurement • Voice of Customer Analysis • Cause and Effect Analysis • Cost Effectiveness Analysis • Waste Analysis • Value Stream Mapping • Pareto Diagram • Benchmarking • Error Proofing • SIPOC (Supplier, Input, Process, Output, Customer) • Histogram • Data Collection Strategy • Hypothesis Testing • Statistical Process Control (SPC) • 5Y Analysis • Quality Costing • Regression Analysis • Set up Time Reduction (SMED)	Yu et al., 2021; Chen et al., 2020; , Antony et al., 2017; Gonzalez et al., 2015; Gonzalez et al., 2014; Antony and Kumar, 2012; George et al., 2005

Q. No.	Constructs	Measures/Items	References/Sources
		• Total Productive Maintenance (TPM) • Non-Parametric Tests (Mann-Whitney Test) • Design of Experiment (DOE) • Critical to Quality Linkage • Mistake Proofing • Quality Function Deployment	
10.	How important is each of the following Critical Failure Factors of Lean and Six Sigma the NHS?	• Lack of Training and Education • Poor Communication • Time Consuming • Poor Project Selection and Prioritisation • Resistance to Culture Change • Lack of Awareness of the need for Lean/Six Sigma • Lack of top management attitude, commitment and involvement • Lack of Awareness of the benefits of Lean/Six Sigma • Poor Organisational Capabilities • Narrow View of LSS as a set of tools, techniques and practices • Lack of experience in Lean/Six Sigma Implementation • Lack of leadership skills and visionary and supportive leadership • Lack of an effective model or	Albliwi et al., 2014; Glasgow et al., 2010; Feng and Manuel, 2007

Q. No.	Constructs	Measures/Items	References/Sources
		roadmap to guide the implementation • Lack of estimation of resources • Lack of resources (Financial, technical, human, etc.) • Ineffective Project Management • Poor Execution • Lack of Clear Vision and Future Plan • Lack of Consideration of Human Factors • Lack of Understanding of the different types of Customers/VOC • Lack of Process thinking and Process Ownership • Misalignment between the project aim, the main goals of the company and customer demand • Lack of application of statistical theory • Diminishing too many resources/ Implementations Cost • Threat of Redundancy • Poor Selection of Candidates for Belt training • Wrong Selection of Lean/Six Sigma tools • Weak link between the CI	

Q. No.	Constructs	Measures/Items	References/Sources
		projects and the strategic objectives of the organisation • Weak Infrastructure • Lack of Employee Engagement and participation/lack of team autonomy • Lack of Understanding of how to get started • Lack of performance measurement system • High Implementation Costs (Overall) • Implementation cost (Financial) • Replicating another organisation's Lean/Six Sigma strategy • Weak Link to suppliers	

Note: from Q. No. 6 to 10 - Scale [From 1 (Completely ineffective) to 5 (Extremely effective)]

Appendix-A

Table-A: Construct Operationalization

Sl. No.	Constructs	Measures/Items	References/Sources
1	Which of the following methodologies and systems have you worked with or applied in the NHS?	Lean LSS Kaizen Plan-Do-Check-Act (PDCA) SS Total Quality Management (TQM) ISO 9000 Rapid Improvement Event (RIE)	Yu et al., 2021; Buttigiet et al., 2016; Taylor et al., 2014;; Dombroski and Mielke, 2013; Culcuoglu et al., 2012; Antony and Kumar, 2012; Barney, 2002
2	How effective is Lean for delivering the following benefits in the NHS?	Defect reductions Speed/Timeliness Patient Safety Cost Savings Patient satisfaction Understanding patient needs/wants Process Flow Improvements Productivity Staff efficiency Standardisation of processes/procedures Ensure compliance Quality of service Revenue enhancement Communication between departments Resource Planning Employee Engagement Medical Inventory Reduction Employee satisfaction	Antony et al. 2018; Honda et al., 2018; Furterer, 2018; Matthias and Brown, 2016; Vermeulen et al. 2014; DelliFraine et al. 2013; Gijo et al., 2013
3	How effective is Six Sigma for delivering the following benefits in the NHS?	Quality of service Ensure Compliance Productivity Staff efficiency Speed/Timeliness Process Flow Improvements Defect reductions Patient satisfaction Patient safety Standardisation of processes/procedures Cost Savings Medical Inventory Reduction Resource Planning Understanding patient needs/wants Employee engagement	Improta et al., 2018; Vago et al., 2016; Stanton et al. 2014; Dickson, 2013 Esimai, 2005

		Employee satisfaction Communication between departments Revenue Enhancement	
4	How effective is Lean Six Sigma for delivering the following benefits in the NHS?	Ensure Compliance Patient Safety Understanding Patients wants/Needs Patient Satisfaction Defect Reductions Quality of Service Speed/Timeliness Cost Savings Productivity Staff Efficiency Standardisation of Processes/procedures Process Flow Improvements Revenue Enhancement Employee Satisfaction Medical Inventory Reduction Resource Planning Communication Between Departments Employee Engagement	Antony et al., 2018; Natale et al., 2014; Jayasinha, 2016; 2014; Stanton et al. 2014
5	How commonly is each of the following tools and techniques applied within the NHS?	Tally Charts Brainstorming 5S Practice Patient Feedback Control/Run Chart Process Mapping Scatter Diagram Failure Mode and Effect Analysis (FMEA) Baseline Measurement Voice of Customer Analysis Cause and Effect Analysis Cost Effectiveness Analysis Waste Analysis Value Stream Mapping Pareto Diagram Benchmarking Error Proofing SIPOC Histogram Data Collection Strategy Hypothesis Testing Statistical Process Control (SPC) 5Y Analysis Quality Costing Regression Analysis Set up Time Reduction (SMED) Total Productive Maintenance (TPM)	Yu et al., 2021; Chen et al., 2020; , Antony et al., 2017; Gonzalez et al., 2015; Gonzalez et al., 2014; Antony and Kumar, 2012; George et al., 2005

		Non-Parametric Tests (Mann-Whitney Test) Design of Experiment (DOE) Critical to Quality Linkage Mistake Proofing Quality Function Deployment	
6	How important is each of the following Critical Failure Factors of Lean and Six Sigma the NHS?	Lack of Training and Education Poor Communication Time Consuming Poor Project Selection and Prioritisation Resistance to Culture Change Lack of Awareness of the need for Lean/Six Sigma Lack of top management attitude, commitment and involvement Lack of Awareness of the benefits of Lean/Six Sigma Poor Organisational Capabilities Narrow View of LSS as a set of tools, techniques and practices Lack of experience in Lean/Six Sigma Implementation Lack of leadership skills and visionary and supportive leadership Lack of an effective model or roadmap to guide the implementation Lack of estimation of resources Lack of resources (Financial, technical, human, etc.) Ineffective Project Management Poor Execution Lack of Clear Vision and Future Plan Lack of Consideration of Human Factors Lack of Understanding of the different types of Customers/VOC Lack of Process thinking and Process Ownership Misalignment between the project aim, the main goals of the company and customer demand Lack of application of statistical theory Diminishing too many resources/ Implementation Cost Threat of Redundancy Poor Selection of Candidates for Belt training	Albliwi et al., 2014; Glasgow et al., 2010; Feng and Manuel, 2007

		Wrong Selection of Lean/Six Sigma tools Weak link between the CI projects and the strategic objectives of the organisation Weak Infrastructure Lack of Employee Engagement and participation/lack of team autonomy Lack of Understanding of how to get started Lack of performance measurement system High Implementation Costs (Overall) Implementation cost (Financial) Replicating another organisation's Lean/Six Sigma strategy Weak Link to suppliers	

Questionnaire Survey

Please answer few questions regarding your profile (you do not need to mention your name, name of the industry/organization, etc.)

1. Do you have any experience applying Continuous Improvement (CI) or Quality Management methodologies either within or alongside the NHS? *

   Yes

   No

   May be

2. What is or was your role within the NHS? *

   ---

3. What department are or were you involved in? *

   ---

4. Has Lean or Six Sigma changed the culture of the NHS? *

   Yes

   No

   May be

5. Which of the following methodologies and systems have you worked with or applied in the NHS? *
Scale
From 1 (Never been used) to 5 (Used continuously)

Methodologies	1	2	3	4	5
Lean					
LSS					
Kaizen					
Plan-Do-Check-Act (PDCA)					
SS					
Total Quality Management (TQM)					
ISO 9000					
Rapid Improvement Event (RIE)					

6. How effective is Lean for delivering the following benefits in the NHS? *
Scale
From 1 (Completely ineffective) to 5 (Extremely effective)

Benefits	1	2	3	4	5
Defect reductions					
Speed/Timeliness					
Patient Safety					
Cost Savings					
Patient satisfaction					
Understanding patient needs/wants					
Process Flow Improvements					
Productivity					
Staff efficiency					
Standardisation of processes/procedures					
Ensure compliance					
Quality of service					
Revenue enhancement					
Communication between departments					
Resource Planning					
Employee Engagement					
Medical Inventory Reduction					
Employee satisfaction					

7. How effective is Six Sigma for delivering the following benefits in the NHS? *
Scale
From 1 (Completely ineffective) to 5 (Extremely effective)

Benefits	1	2	3	4	5
Quality of service					
Ensure Compliance					
Productivity					
Staff efficiency					

Speed/Timeliness (decrease length of stay, decrease waiting time, etc.)
Process Flow Improvements
Defect reductions (medication errors, infection errors, process defects, etc.)
Patient satisfaction
Patient safety
Standardisation of processes/procedures
Cost Savings
Medical Inventory Reduction
Resource Planning
Understanding patient needs/wants
Employee engagement
Employee satisfaction
Communication between departments
Revenue Enhancement

8. How effective is Lean Six Sigma for delivering the following benefits in the NHS? *
Scale
From 1 (Completely ineffective) to 5 (Extremely effective)

Benefits	1	2	3	4	5
Ensure Compliance					
Patient Safety					
Understanding Patients Wants/Needs					
Patient Satisfaction					
Defect Reductions					
Quality of Service					
Speed/Timeliness					
Cost Savings					
Productivity					
Staff Efficiency					
Standardisation of Processes/procedures					
Process Flow Improvements					
Revenue Enhancement					
Employee Satisfaction					
Medical Inventory Reduction					
Resource Planning					
Communication Between Departments					
Employee Engagement					

9. How commonly is each of the following tools and techniques applied within the NHS? *
Scale
From 1 (Never been used) to 5 (Used continuously)

Tools and Techniques	1	2	3	4	5
Tally Charts					
Brainstorming					
5S Practice					
Patient Feedback					
Control/Run Chart					
Process Mapping					

Scatter Diagram
Failure Mode and Effect Analysis (FMEA)
Baseline Measurement
Voice of Customer Analysis
Cause and Effect Analysis
Cost Effectiveness Analysis
Waste Analysis
Value Stream Mapping
Pareto Diagram
Benchmarking
Error Proofing
SIPOC
Histogram
Data Collection Strategy
Hypothesis Testing
Statistical Process Control (SPC)
5Y Analysis
Quality Costing
Regression Analysis
Set up Time Reduction (SMED)
Total Productive Maintenance (TPM)
Non-Parametric Tests (Mann-Whitney Test)
Design of Experiment (DOE)
Critical to Quality Linkage
Mistake Proofing
Quality Function Deployment

10. How important is each of the following Critical Failure Factors of Lean and Six Sigma in the NHS? *

Scale
From 1 (Least Important) to 5 (Crucial)

Critical Failure Factors	1	2	3	4	5
Lack of Training and Education					
Poor Communication					
Time Consuming					
Poor Project Selection and Prioritisation					
Resistance to Culture Change					
Lack of Awareness of the need for Lean/Six Sigma					
Lack of top management attitude, commitment and involvement					
Lack of Awareness of the benefits of Lean/Six Sigma					
Poor Organisational Capabilities					
Narrow View of LSS as a set of tools, techniques and practices					
Lack of experience in Lean/Six Sigma Implementation					
Lack of leadership skills and visionary and supportive leadership					
Lack of an effective model or roadmap to guide the implementation					
Lack of estimation of resources					
Lack of resources (Financial, technical, human, etc.)					
Ineffective Project Management					
Poor Execution					
Lack of Clear Vision and Future Plan					

Lack of Consideration of Human Factors
Lack of Understanding of the different types of Customers/VOC
Lack of Process thinking and Process Ownership
Misalignment between the project aim, the main goals of the company and customer demand
Lack of application of statistical theory
Diminishing too many resources/ Implementation Cost
Threat of Redundancy
Poor Selection of Candidates for Belt training
Wrong Selection of Lean/Six Sigma tools
Weak link between the CI projects and the strategic objectives of the organisation
Weak Infrastructure
Lack of Employee Engagement and participation/lack of team autonomy
Lack of Understanding of how to get started
Lack of performance measurement system
High Implementation Costs (Overall)
Implementation cost (Financial)
Replicating another organisation's Lean/Six Sigma strategy
Weak Link to suppliers

We have addressed all the comments of the reviewer, and the manuscript has been revised accordingly. These suggestions helped us to improve the quality of the article further. The authors would like to thank the reviewer for the positive and constructive feedback.

Reviewer: 1

Recommendation: Minor Revision

Comments:

Referee Report

An Evaluation of Lean and Six Sigma Methodologies in the National Health Services (IJQRM-05-2021-0140.R1)

It seems that the present version of the manuscript is far improved than the earlier version. I must appreciate the author(s) to address and sewing reviewers' comments nicely in the manuscript.

I have few observations regarding the paper –

1) In table 1, please mention the full form of the MBB, BB, GB, DMAIC, DMADV, BPM, etc., for ease of readability.

Response: Thank you for the suggestion. The manuscript has been revised as per the comment, and changes are highlighted in blue colour (Section 2, Page No. 5).

2) Author(s) have written appendix A two times in the manuscript with the same data, which is redundant. I request the author(s) to remove one of the redundant appendixes.

Response: Thank you for the suggestion. The manuscript has been revised as per the comment (Appendix-A, Page No. 44).

3) As highlighted by reviewer 2, author(s) should mention the limitations of the study explicitly in the conclusion section as implications and future research directions have been mentioned. Please re-look into it.

Response: Thank you for the suggestion. The manuscript has been revised as per the comment, and changes are highlighted in blue colour (Section 6, Page No. 35).

Additional Questions:

1. Originality: Does the paper contain new and significant information adequate to justify publication?: **Yes**

Response: Thank you for the feedback.

2. Relationship to Literature: Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any significant work ignored?: **Yes**

Response: Thank you for the feedback.

3. Methodology: Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed appropriate?: **Yes**

Response: Thank you for the feedback.

4. Results: Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together the other elements of the paper?: **Yes**

Response: Thank you for the feedback.

5. Implications for research, practice and/or society: Does the paper identify clearly any implications for research, practice and/or society? Does the paper bridge the gap between theory and practice? How can the research be used in practice (economic and commercial impact), in teaching, to influence public policy, in research (contributing to the body of knowledge)? What is the impact upon society (influencing public attitudes, affecting quality of life)? Are these implications consistent with the findings and conclusions of the paper?: **Yes**

Response: Thank you for the feedback.

6. Quality of Communication: Does the paper clearly express its case, measured against the technical language of the field and the expected knowledge of the journal's readership? Has attention been paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc.: **Yes**

Response: Thank you for the feedback.