Exploration, development and integration of Lean Six Sigma approaches with "green" environmental practices.

MARSH, James A.

Exploration, Development and Integration of Lean Six Sigma Approaches with "Green" Environmental Practices

James Marsh

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Abstract

Lean Six Sigma (LSS) has the capability to provide organisations with increased levels of competitiveness in terms of more consistent quality, lower customer lead times and reduced costs. What is lesser known is that when deployed effectively, it can also provide organisations with additional environmental or "green" benefits.

With organisations facing ever increasing demands for reducing CO_2 levels from global environmental legislation, the motivation for the research was to gain knowledge and understanding of the current status of LSS and Environmental Management practices within the Global LSS community. In addition the researcher intended to gauge the demand for "Green" LSS tools and techniques and an associated framework.

Consequently the fundamental aim of the research and resulting thesis has been to explore, develop, test and implement Environmental LSS methodologies that can be applied by organisations and also to develop a structured operational assessment framework that can increase sustainability of LSS whilst simultaneously garnering environmental improvements.

The initial part of the research is based on the review of the literature on LSS, and its recent evolution into different versions of Environmental Lean and/or Six Sigma and how this relates to Environmental Management Systems and current/future environmental legislation in the UK and Globally. In addition, the development and deployment of a Global LSS survey received over 450 responses from a broad array of companies, organisational functions and hierarchical levels, which has confirmed the potential environmental benefits of LSS and its suitability for combination with environmental management practices.

Using evidence and analysis from the Global LSS survey and the development, testing and industry case study of an Environmental 5S Sustainability Audit (E5S-SA), it has been possible to develop an Environmental Lean Six Sigma Sustainability Assessment (ELSSSA) Framework that can be

deployed and tailored to suit the requirements of a wide range of organisations from different specific geographic locations, industry sectors and company structure types.

The research findings have clarified the unique differences that exist within manufacturing and service sectors, specific geographic locations and organisational structure types in relation to LSS and Environmental Management. In addition it has been discovered that the majority of the LSS community have experienced environmental benefits from their LSS projects with the reduction in energy consumption being the biggest benefit experienced.

Through the development and testing of the ELSSSA tool in an industry scenario within the transport sector, it has been possible to deliver a solution that has provided practical results and structured feedback to an organisation quickly and effectively through the E5S-SA process.

In terms of opportunities and lessons learnt from the research it would be advantageous to conduct further research via the Global LSS survey to extent down to a country specific level to provide more precise guidelines to geographic locations. This would broaden its appeal and usefulness within businesses interested in combining the use of LSS and Environmental Management

Finally it would be beneficial to conduct further development and testing of the ELSSSA tools to a wider range of business sectors to garner more knowledge and feedback on the approaches created by the researcher.

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List of Abbreviations

ANOVA	Analysis of Variance
ASQ	American Society for Quality
BB	Black Belt
CCA	Climate Change Agreement
CCC	Climate Change Committee
CEO	Chief Executive Officer
CH	Champion
BPI	Business Process Improvement
DMAIC	Define, Measure, Analyse, Improve and Control
DOE	Design of Experiments
DPMO	Defects per million opportunities
E5S	Environmental 5S
E5S-SA	Environmental 5S Sustainability Audit
E7W	Environmental 7 Wastes
ECIP	Environmental Continuous Improvement Plan
ELSS	Environmental Lean Six Sigma
ELSSSA	Environmental Lean Six Sigma Sustainability Assessment
EMS	Environmental Management Systems
EPA	Environmental Protection Agency
ESOP	Environmental Stand Operating Procedures
EVSM	Environmental Value Stream Mapping
FMEA	Failure Mode Effect Analysis
GCC	Global Climate Change
ISO	International Standards Organisation
KPI	Key Performance Indicator
LSS	Lean Six Sigma

MBB	Master Black Belt
NVA	Non value added
PDA	Personal Digital Assistant
PLC	Public Limited Company
POC	Proof of Concept
PTS	Partnerships
QCD	Quality, Cost and Delivery
SBAC	Society of British Aerospace Companies
SME	Small to Medium Sized Enterprise
SMED	Single Minute Exchange of Dies
SPC	Statistical Process Control
SPSS	Statistical Package for Social Sciences
ST	Sole Trader
TPS	Toyota Production System
TM	Team Member
TR	Trainer
VOC	Voice of the Customer
VSM	Value Stream Mapping
YB	Yellow Belt

List of Publications and Conference Papers

1. Marsh J, Perera T, Ratnayake V, and Lanarolle G. (2008) **Development of a 5S Sustainability Model for use with Lean Six Sigma projects** *3rd International Conference on Six Sigma* - Edinburgh, December 15th-16th

2. Marsh J. and Perera T.(2009) **Exploration of the Impact of Business Improvement approach Lean Six Sigma on the Environment** *5th International Conference on Environmental, Cultural, Economic and Social Sustainability* - Mauritius, January 5th-7th

3. Marsh J. (2009) **Conducting a Green 5S Sustainability Audit** *Inaugural WCBF Green Six Sigma Conference* - Chicago, May 13th-14th

4. Marsh J. and Perera T. (2010) **ISO 14001: Analysis into its strengths and weaknesses, and where potential opportunities could be deployed for tomorrows Global Business** *6th International Conference on Environmental, Cultural, Economic and Social Sustainability* - Ecuador, January 5th-7th

5. Marsh J, Perera T, Ratnayake V, and Lanarolle G. (2010) **Lean Six Sigma: Exploring future potential and challenges** *2nd European Research Conference on Continuous Improvement and Lean Six Sigma* – Glasgow, January 18-20th

6. Marsh J. (2010) **Key Factors Impacting the Long Term Sustainability of Lean Six Sigma and Proposed Strategies for Today's Global Businesses** *Operational Excellence Conference*- London, May 18th

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Practitioners from director to operative workers levels all of whom have demanding roles managed to take the time to be involved in the research and for this I am very grateful. In addition the broadcasting of my research has involved feedback from journal referees and editors whose comments and suggestions have been much appreciated.

Contributions should also be acknowledged for the many individual and companies that took part in the proof of concept testing and to BAA Glasgow who provided significant assistance by agreeing to collaborate in the research and provide suggestions and feedback.

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Last but by no means least I am eternally indebted to my partner Shaaron for her long term support, academic experience and assistance with the research and to my son Alexander for his patience whilst I have been writing up the thesis, he will be very pleased that I will now have more time to spend with him.

Declaration

I wish to declare that the work that is documented with this thesis is my own original research. As the research has evolved and developed various sections of the work have been presented at conferences and journal publications on an ongoing basis throughout the PhD study. However these publications and conference papers represent my own work with contributions from various academic and industry colleagues.

1 Introduction

The purpose s of this initial chapter is to:

- Present and discuss the background to the research
- Clarify the objectives of the research
- Identify the outline research methodology
- Provide the general structure of the thesis

1.1 Background

The improvement of businesses globally via the use the various approaches and tools/techniques such as Lean and Six Sigma has been increasing year on year for over two decades at a considerable rate (Pepper and Spedding 2010). These approaches have their roots in theories and practices pioneered by the likes of Taylorism, Whitney, Henry Ford, Deming, and Toyota, which has led to the aforementioned more contemporary approaches being applied by companies such as Motorola, GE, Allied Signal (Coronado and Anthony 2002) and numerous consulting and academic organisations.

The influence of Lean Six Sigma (LSS) started in the manufacturing sector but has gone on to see organisations from virtually every industry sector achieve huge benefits in terms of improving the quality and consistency of their products/processes and service. It has also seen large reductions in lead times for customer delivery and in costs from wastes such as excessive inventories, scrap, over processing and transportation. In addition to this businesses have saved Billions from the successful deployment of Lean (Burton and Boeder 2003) and Six Sigma (Henderson and Evans (2000).

In parallel the need for businesses to become more environmentally friendly due to drivers such as government, communities, customers and suppliers have occurred. What used to be a "nice to have" in terms of reducing the carbon footprint of an organisation has changed significantly in recent years and looks likely to continue as new and increasingly demanding legislation is implemented both nationally and globally. These agreements such as the Climate Change Agreement (CCA) in the UK

(Martin and Wagner 2009) and the newly outlined "Durban Platform" (Stavins 2012) in December 2011, which supplements the 1997 Kyoto Protocol (Manne and Richels 1998), will put businesses under increasing pressure to conform to increasing carbon reductions.

These agreements are required due to increasing evidence of Global Climate Change (GCC) (McMichael 2004). There has been widespread debate over the legitimacy of GCC over the last four decades however the evidence is difficult to dispute. Records from the Hadley Centre Met Office (Stern 2007) show since the early 1880's temperatures have risen by 0.7°C and sea levels have risen by 0.5M. In addition, over the last 100 years the arctic icecap area has decreased from 13 to 11 Million Km^2 and fossil fuel emissions have increased from less than 1 billion tons to over 7 billion tons. The impact of these changes in recent years has been severe flooding, forest fires, heat-waves, droughts and storms around the globe.

The prediction is that by 2050 in the UK temperatures will have increased on average by 1.5°C to 2.0°C and other EU countries such as Spain could see increases on average of 5°C and 7°C (BBC News 2012). These significant changes are having a huge impact on the indigenous environments globally and are leading certain plants and animal life becoming extinct (Hanson et al 2006) or they will do so in the future if the situation does not change.

Even if some politicians and scientists are split in their agreement (Stainforth 2005) with the evidence and predictions that are being presented, few can argue that if we use less of our valuable resources, be they mineral, animal or vegetable, then this is a positive result even if the doubters of climate change prove to be correct.

Traditionally Business Process Improvements (BPI) approaches such as Lean and or Six Sigma have been implemented separately to Environmental Management practices (EMS) such as ISO 14001 (Tibor and Feldman 1995), however, there can be a natural positive synergy between them. This synergy can result in both the traditional benefits of the LSS approach and furthermore environmental impacts can be reduced creating a potential "double whammy" for businesses. This will be outlined and discussed in more detail in the literature review in Section 2.

In principle, there is huge potential for organisations such as SME's through to large PLC's to garner high business benefits through the application of LSS approaches and, in parallel, be capable of reaching environmental targets at minimal additional cost. However what is less clear is how combined approaches such as this can be developed and applied in organisations in a sustainable manner. LSS in its current state has issues relating to its successful sustainability in organisations (Mehta 2004) and simply applying LSS in its current format can also be the cause negative environmental impacts as well as positive ones.

These reasons and others outlined in this section will clarify the need for a suitable framework that will facilitate the traditional benefits of LSS in parallel with environmental improvements that can be deployed in a sustainable manner.

1.2 Research Aims, Objectives and Justification

Although the potential benefits of using LSS to gain reductions in environmental wastes are becoming more widely recognized (Section 2) it is still embryonic in its evolution. This thesis has the following 5 key aims and subsequent objectives which will provide an original contribution to the research in this area.

Aim 1 To establish how Lean and/or Six Sigma approaches are being developed and applied to garner Green\Environmental business benefits.

Objectives

1. To research and explain the environmental business benefits that can be gained from using LSS
2. To describe the evolution of "Environmental" Lean and/or Six Sigma Approaches
3. Discuss the problems with current EMS approaches and how Environmental legislation can impact todays organisations

Aim 2 To develop a Proof of Concept LSS Sustainability Assessment Process

Objectives

1. To critically assess traditional LSS assessment methods
2. Identify a suitable software platform
3. Test the viability of a suitable software platform via an industry POC pilot case study.

Aim 3 Identify the main requirements for an Environmental Lean Six Sigma Sustainability Assessment (ELSSSA) process

Objectives

1. Develop a LSS survey to identify the current status of LSS and Environmental Management
2. Administer the LSS survey to a large international sample of LSS professionals
3. Analyse the results statistically to establish meaningful conclusions about current practices and perceived needs in LSS and Environmental Management

Aim 4 Develop, Implement and Assess the ELSSSA Methodology

Objectives

1. Evaluate and select a suitable LSS tool for the ELSSSA process
2. Develop the ELSSSA methodology for the selected LSS tool and technique
3. To test its viability and optimise in a "real life" industry scenario.

Aim 5 Develop a suitable final framework with which to implement the ELSSSA process within typical organisations

Objectives

1. Establish the main requirements for the ELSSSA framework

2. Clarify the key criteria guidelines for the ELSSSA Framework

3. Integrate the findings and lessons learnt from the earlier stages of research to produce a final framework structure

1.1 Research Methodology

Research for this PhD began in September 2007 with an exploratory literature review and the research was subsequently completed in March 2012. Table 1.1 provides a chronology for the research work undertaken.

Months	Research Stage	Research Work
1-6	Exploratory Research	Outline literature review
6-12	Research Evaluation	Evaluation and selection of software platform for outline concept
12-24	Research Testing	Testing platform with Sri Lanka Textiles Company for convention LSS tool
24-48	Inductive Research	Further literature review and Global Environmental LSS Survey development and analysis
36-48	Research Design and Test	Development and internal testing of an Environmental LSS tool and subsequent ELSSSA method
42-48	Research Validation	Industry Case study with BAA Glasgow of ELSSSA for Environmental 5S tool
48-54	Final Development	ELSSSA Framework

Table 1.1: Research Chronology

1.3 Thesis Outline

The Table 1.2 shows the structure of the thesis. Each chapter focuses on a particular aspect of the research. These chapters provide a record of the work undertaken and the original contribution to knowledge that had been achieved from the research.

Chapter	Title	Deliverable
1	Introduction	Research objectives
2	Literature Review	Research questions
3	Research Methodology	Research methods discussed and selected, suitable software platform evaluated and tested in Pilot Study
4	Global LLS Survey Development	Survey developed, tested and minimum sample size return achieved
5	Global LSS Survey Results	Survey results
6	Analysis of Global LSS Survey	Analysis of key characteristics
7	Discussion of Results and Analysis	Conclusions from the results and analysis
8	Research, Development and Implementation of a ELSSSA Methodology	Validated E5S-SA tool and industry case study
9	ELSSSA Framework Development	Formalized ELSSSA framework
10	Conclusions and Recommendations	Research conclusions, contribution to knowledge and recommendations for further work

Table 1.2: Thesis Structure

Chapter 1 – Introduction

The first chapter in this thesis acts as the foundation for the research and it outlines the relevance and fundamental need. It also clarifies the structure and overall objectives of the research to be achieved.

Chapter 2 – Literature Review

Reviews how LSS has evolved, its business benefits and the potentials weaknesses including sustainability that can be experienced through its deployment. It also clarifies how LSS can achieve environmental benefits and that organisations are developing their own Environmental methodologies. Finally it discusses current and future environmental management practices and environmental legislation and the opportunity that LSS may provide to organisations to reduce environmental impacts.

Chapter 3 – Research Methodology

This will outline the research philosophy and methods evaluated and selected by the researcher. Describes and justifies the need for the initial pilot study. It investigates the traditional auditing methods and their limitations, which are subsequently considered in the requirements of software platform evaluation. A Proof of Concept (POC) for a conventional LSS tool is developed and tested in an industrial scenario.

Chapter 4 – Global LSS Survey Development

Describes the methodology chosen for the Global LSS survey and it justifies its development and validation through internal and external testing. In addition, it calculates the minimum sample size required for the analysis and collects responses it excess of this number.

Chapter 5 – Global LSS Survey Results

This chapter presents the results from the Global LSS Survey in a series of graphs and charts.

Chapter 6 – Analysis of Global LSS Survey

Clarifies the methodology employed to analyse the data and performs statistical analysis on each of the key characteristics identified.

Chapter 7 – Discussion of Results and Analysis

Critically examines and discusses the results from the Global LSS survey and the outcomes from the statistical analysis for each of the key characteristics.

Chapter 8 – Research, Development and Implementation of an ELSSSA Methodology

This section outlines the evaluation of the ELSSSA methodology including key selection criteria. It also describes the objectives and structure of E5S and its development and validation into E5S-SA and the case study implementation at BAA Glasgow.

Chapter 9 – ELSSSA Framework Development

Reviews the knowledge garnered from the research and embodies and develops these findings into a structured 5 phase ELSSSA Framework.

Chapter 10 – Conclusions and Recommendations

Presents the conclusions made from the research, the contributions made to knowledge and clarifies recommendations for further work.

2 Literature Review

2.1 Introduction

This chapter reviews the literature in the areas of Lean Six Sigma, its evolution into variations of Environmental Lean and/or Six Sigma and this is supplemented by discussion of Environmental Management Systems (EMS) and environmental legislation. The literature review involved using a variety of research techniques. These included detailed searches of library catalogues, international journal publications, internet sites of respected publishing companies and industry bodies. In addition to this, guidance was obtained from academics and fellow industry practitioners. Books, academic papers, training sessions and attendance at several international conferences generated valuable additional information used in this review.

The literature review yielded the following themes and will provide an understanding of:

- A background to Lean Six Sigma, its business benefits and limitations
- The environmental advantages and disadvantages of Lean Six Sigma
- The evolution of Environmental or "Green" Lean and/ or Six Sigma approaches
- Limitations and weaknesses of conventional EMS approaches such as ISO14001
- Current and future environmental legislation and the problems faced by organisations

2.2 Lean Six Sigma (LSS)

The business improvement approach LSS has evolved over a century long journey to what it is today, which is a globally accepted methodology that has saved organisations many billions of pounds and is applicable to virtually any industry sector. This element of the literature survey will describe this journey, its benefits and limitations.

2.2.1 Lean

The term "Lean" was coined to describe Toyota's business during the late 1980s by a research team headed by Jim Womack, PhD, at MIT's International Motor Vehicle Program. Lean Manufacturing

(Womack and Jones 2003) or Lean Production it became popularly known in the 1990's was deployed widely in the USA and subsequently out to Europe and Asia. This popularity has continued to grow due to its pertinence for other business sectors in particular service sectors such as Healthcare (Jones, Mitchell 2006) and Governmental, (Krings and Levine 2006) it now tends to be known simply as "Lean"

Lean is defined as the reduction of business wastes within a process or system using a systematic and continuous approach across the whole value stream from customer order through to delivery (Hines 1997). The resulting benefits include reduction in the lead-time to get a product or service to the customer and significantly reduced costs throughout the value stream. Many refer to the 5 Lean Principles (Womack and Jones 1990) which is a 5 step process developed to take an organisation towards a lean culture. This process is visually demonstrated in Figure 2.1.

Within each of the lean principles, various tools and techniques are utilised to reduce wastes, these include 5S (Hirano 1996), 7 Wastes (Shingo, Shingō and Dillon 1989), Value Stream Mapping (Rother and Shook 2003) and SMED (Single minute exchange of dies) (Shingō 1985).

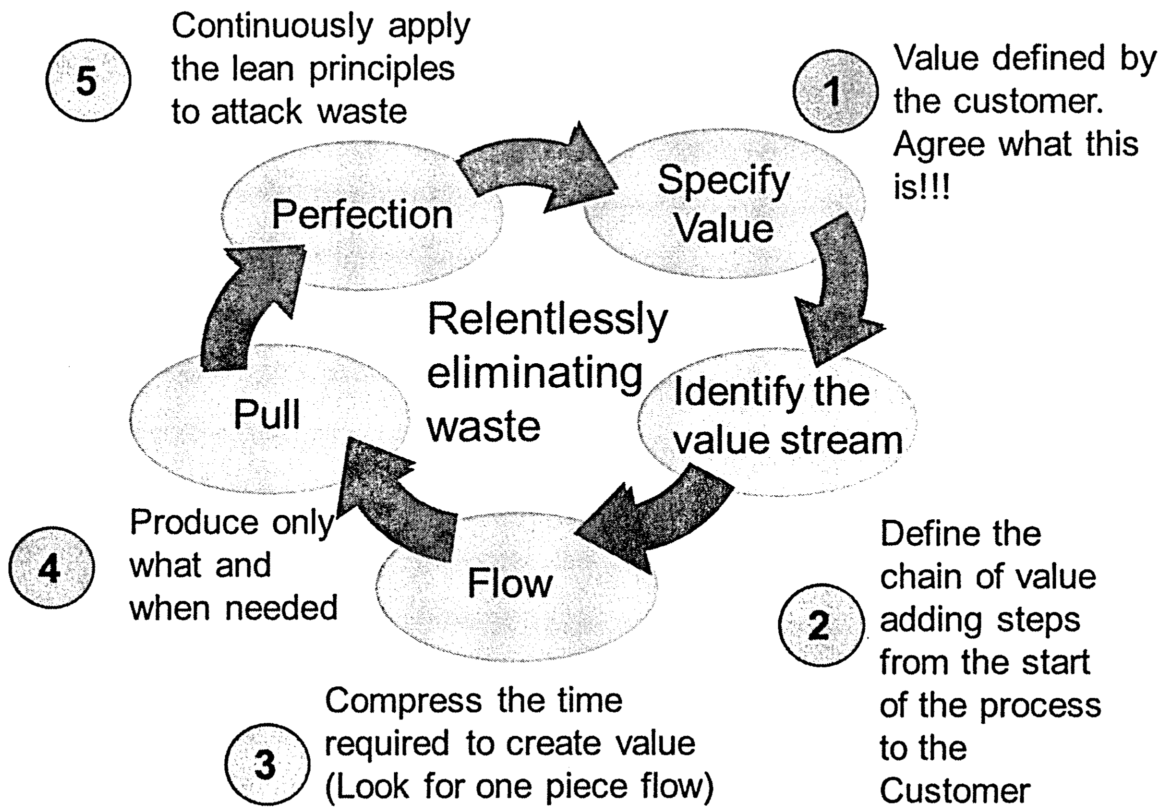


Figure 2.1: 5 Lean Principles (Womack and Jones 1990)

The reduction of wastes is divided into value added (George and Rowlands 2004), non-value added (NVA) and necessary but non value added (NNVA) activities. Value added activities within an organisation are those which the customer is willing to pay for a given product and/or service, anything else is either NVA or NNVA and wherever possible should be eliminated or reduced. NNVA activities could include 100% inspection of a component which is deemed as essential however if the capability of the manufacturing processes in improved this activity could be reduced or eliminated by the manufacturer, therefore saving time and money.

The original philosophy and roots of Lean can be traced back to Toyota Production System (TPS) from the 1960's (Watanabe and Toyoda 1983). Lean takes many of the TPS principles and enhances them with additional methods and uses a more structured approach. However, the original ethos of changing the culture at all organizational levels and employee empowerment remains.

2.2.2 Six Sigma

Six Sigma (Harry 1988), was originally developed by Motorola in the mid 1980's and is increasingly popular today being utilised in virtually all industry sectors. Bill Smith, a Motorola engineer, conducted a study in 1985 which found that the number of latent defects was directly proportional to the total number of defects found during manufacture. This research and the opportunities clarified led to Motorola announcing the Six Sigma approach in 1987. Six Sigma is a focused improvement approach aimed at all levels of an organisation with the fundamental objective to identify and significantly reduce the number of defects through the improvement of an organisations processes capability and control. Like Lean it was initially prevalent within manufacturing but subsequently broadened to other business sectors and departmental functions including transactional (Antony 2004) and customer services (George 2003)

The approach focuses on reducing the level of variation within processes and the term "Six Sigma" originates from the principles of process capability (Chou 1989). It is deemed that for a process to exhibit Six Sigma quality, it must operate with defect levels which are less than 3.4 defects per million opportunities (DPMO). This is seen as the desired standard for world class companies to aspire to and meet. Six Sigma also incorporates the philosophy of data driven decision-making, which is incorporated to avoid assumptions and guesswork wherever possible.

Motorola's success with Six Sigma (savings in excess of £10 Billion over the last 20 years) has influenced many thousands of other organisations to embrace the principle of the Six Sigma approach most notably General Electric (GE) (Eckes 2001) and Honeywell (Caulcutt 2001)

The main reasons for this success are that Six Sigma follows a structured approach, which has a clear customer focus on achieving measurable financial returns for a defined project. This approach is most widely known in its abbreviated form DMAIC, (George and Rowlands 2004) which stands for Define, Measure, Analyse, Improve and Control. Each phase of the DMAIC approach has objectives to meet and gate reviews to ensure that elements of the process are not missed.

The DMAIC gated approach also combines the statistical element, with the ethos of strong management commitment, training and support. Using the Six Sigma DMAIC approach each project should have a defined Six Project team (Antony and Banuelas 2002), which contains Champions (usually influential company members), Master Black Belts (trainers, mentors and coaches), Black Belts (project leaders), Green Belt (project implementers) and Yellow Belts (project support, team members). Having a team approach such as this is aimed to provide full stakeholder commitment as the project progresses through each the gate milestones.

2.2.3 Evolution of Lean Six Sigma (LSS)

The origin of who coined LSS is very difficult to define in comparison to Lean or Six Sigma, where there is plenty of research and knowledge. However, it is commonly thought that the term LSS was used in the late 1990's by Allied Signal, (Arnheiter and Maleveff 2005) Maytag (Furterer and Elshennawy 2005) and BAE Systems (Sheridan 2000). All three started their own Lean Six Sigma programmes at similar times, therefore it is difficult to clarify exactly who defined it first but it is commonly thought to be one of these three organisations. Other potential contenders include Northrop Grumman and Lockheed Martin. What is certain is that the concept of the Lean Six Sigma approach was heavily biased towards the aerospace and manufacturing business sector in its early life span.

Allied Signals' (now Honeywell) strategy was to train employees in both Lean and Six Sigma whilst creating a bespoke roadmap that combined both approaches. Initially it was called "Six Sigma Plus" (Caulcutt 2001) and this evolved in a Lean Six Sigma Green Belt program.

Meanwhile Maytag (Whirlpool) developed an in-house "Lean Sigma" program (Smith 2003). The objective was to train Black Belts who were masters in both Lean and Six Sigma. It was around this time that Maytag developed a roadmap that used the DMAIC approach but in a radically reduced time span not unlike a Lean Kaizen, this was called a "Lean Sigma event"

Another early example of Lean Six Sigma was at BAE Systems Controls in Fort Wane, Indiana. They started their own combined Lean and Six Sigma deployments in 1997 (Sheridan 2000). By the year

2000 this combined focus of the two approaches had spread further afield through to BAE Systems in the UK through to the Eurofighter Typhoon Military aircraft programme. BAE Systems soon started using the combined approach with their 2nd and 3rd tier suppliers as part of the Manufacturing Excellence programme which is governed by SBAC (Society of British Aerospace Companies)

It wasn't long before other large organisations followed the examples of these two organisations with their own LSS approaches. These companies included Lockheed Martin (Joyce 2004) who had an approach, which rather than having a balance between the two approaches, would bias a project towards Lean or Six Sigma depending on the objectives or needs.

Another Aerospace company that saw the benefit of a combined approach was Northrop Grumman (Furterer 2004). They had already begun their Lean journey by following the principles of Lean thinking, when they also identified the benefits of Six Sigma. Rather than implement the two approaches separately they decided to integrate their Kaizen (Schneiderman 1986) and so called "Workout" (Six Sigma) events.

Since the turn of the century Lean Six Sigma as a combined approach has gathered speed in terms of market penetration at a dramatic rate. It has gained popularity in just about every conceivable market sector and looks set to continue to grow and businesses continue to see considerable benefits.

2.2.4 Similarities and Differences between Lean and Six Sigma

Lean and Six Sigma are both business improvement methodologies but they have some important fundamental differences. These differences are well documented in numerous academic research papers (Andersson, Eriksson, and Torstensson 2006) but can be summarised in Figure 2.2.

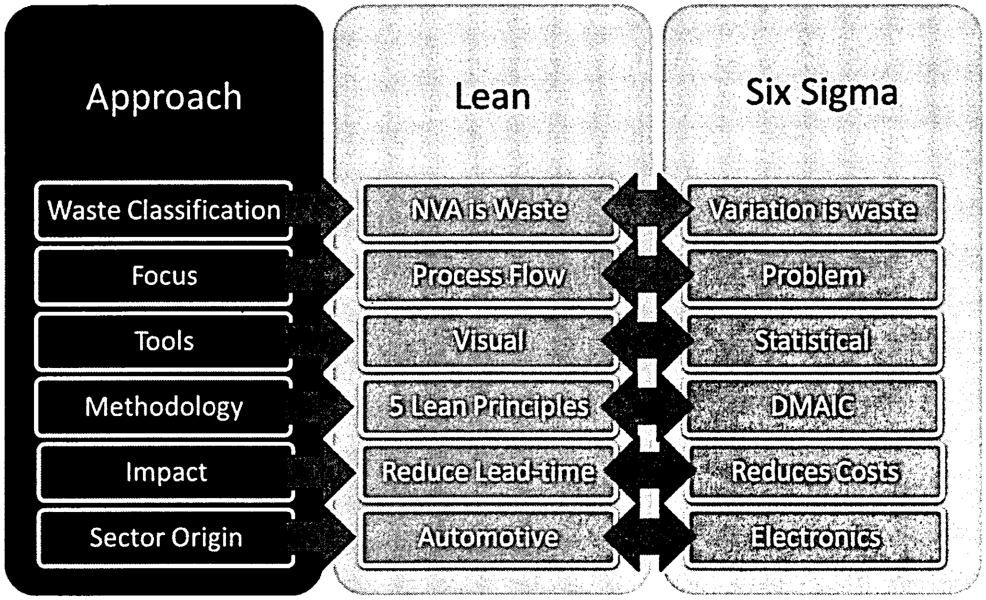


Figure 2.2: Key differences between Lean and Six Sigma Approaches

In simplistic terms, Lean is much more than just about reducing and eliminating process wastes, it is a philosophy than can be applied in a continuous form as depicted in Figure 2.1. This is seen as a never ending cycle of improvement which can be deployed for years if not decades as can be seen with organisations such as Toyota (Sugimori et al 1977) that as the founding fathers have been doing this for over fifty years.

Six Sigma meanwhile concentrates on the reduction/elimination of problems, which could manifest themselves in the form of defects or variation. It can used to solve virtually any type of problem (Hahn 1999) where the solution is unknown to the organisation, through the use of a range of data driven problem solving tools and techniques. The Six Sigma approach tends to be much more finite than Lean and mostly lasts over a period of weeks to months.

Another key difference between the two approaches is in terms of the focus of the improvement. Lean projects focus on the actual flow of a product and/service through the value stream and the improvement of its velocity, whilst a Six Sigma project concentrates very much on the problem that needs to be solved and improving its consistency in line with customer requirements.

Probably the biggest difference between the two methods is in the tools that they use. Obviously they are different in terms of specific names and titles but they are also different in their application. Many of the tools within the Lean toolkit are very visual and designed to be easy for the user to understand and represent. This contrasts with Six Sigma where the tools in the main are much more statistical and are more specialized. Due to the inherent complexities of the statistical element of Six Sigma, the majority of Green Belt and Black Belt users have at their disposal statistical software such as Minitab (Henderson 2006) or to a lesser degree SPSS. These packages became very popular in the Six Sigma community in the late 1990's, prior to this, users had to be very adept at statistical calculations which limited the deployment of Six Sigma into industry.

In terms of similarities though there is a significant amount between Lean and Six Sigma. Both approaches focus heavily on the customer requirements. These requirements are defined in the 5 Lean principles at the 1st step of the methodology and similarly with Six Sigma and DMAIC these requirements are clarified in the Project Charter (Hahn, Doganaksoy and Hoerl 2000) in the Define phase. This customer focus is one of the key elements why both these approaches have had the considerable success that they have and is a key reason why, when combined, they can work well together.

They are also similar in the way they focus on a team approach. Lean concentrates on empowering operations employees in particular to be able to generate and implement ideas and solutions. This change in culture is from the authors experience like a breath of fresh air for operational employees who now feel engaged and valued. Similarly Six Sigma embraces a team approach through having various roles such as Champions, Yellow Belts, Green Belts and Black Belts. These different belts have varying responsibilities and capabilities, with the Green and Black Belts usually requiring specialist training.

Both Lean and Six Sigma when implemented correctly also share the characteristic of having internal review mechanisms which center the improvement team's attention to specific gates that must have certain criteria fulfilled before they can continue onto the next phase

The final similarity between the two separate approaches is that in many cases they can share certain tools and techniques. From personal experience of implementing both Lean and Six Sigma projects, tools such as Brainstorming are commonly used by either approach for generating ideas and solutions. FMEA (Failure Mode Effect Analysis) (Hoerl 2001) is also a practical tool that can be used by either approach for clarifying and prioritizing the seriousness of a problem in terms of severity, occurrence and ease of detection. During the initial phase of both Lean and Six Sigma, the technique Voice of the Customer (VOC) (Perez-Wilson 1999) is also commonly used by the two individual approaches. Finally the mistake proofing tool Poke Yoke (Arnheiter and Maleyeff 2005) is also commonly used on Lean or Six Sigma deployments for clarifying opportunities to both reduce wasteful operations and solving problems to minimize defects.

This crossover of tools and techniques is probably one of the core reasons why many organisations as clarified earlier in the section decided to combine the two separate approaches to minimize duplication of effort and having separate teams which increase employment budgetary requirement for businesses (Snee 2010).

2.2.5 Benefits of LSS

There is considerable research concerning the benefits of Lean Six Sigma (Arnheiter and Maleyeff 2005) across all the major business regions of the world and business sector types (George 2003). From a personal perspective and the researcher's own experience of managing over a hundred Lean and/or Six Sigma projects globally it has yielded financial benefits in excess of £40 million. From the period of 1995 to 2000 these projects were conducted using Lean and Six Sigma separately for different deployment teams. Even though these early projects yielded significant benefits in terms of reduced costs, it soon became apparent that the combined use of the tools and techniques would garner even higher benefits and potentially reduce duplication of effort.

The subsequent personal projects delivered from 2000 to date which have utilized a combined use of Lean and Six Sigma have achieved a higher degree of success than the use of the two approaches separately (Delgado 2010). The most notable benefits apart from the most obvious of QCD are the changes achieved in culture within the business. By having a structured LSS approach it has been possible to involve different stakeholder levels throughout the different phases and gain important "buy in" to realise real business benefits.

Antony, Escamilla and Caine (2003) also found that when combined, companies who practised the approach could expect to see faster responses to customers, improved process capability, lower cost of poor quality and greater flexibility throughout the value chain. Smith (2003) also described how the combination of Lean and Six Sigma provided a "one-two punch" making it a formidable business improvement methodology when implemented correctly in a controlled and carefully planned manner.

From a case study perspective, Sharma (2003) found that when implemented as a combined approach within a battery manufacturer the synergy of Lean and Six Sigma provided a strategic and operational advantage. The Lean tools and techniques provided the quick wins which are necessary to garner the buy in of the approach whilst Six Sigma gave a structured process framework, which could be transferred to other parts of the business.

What is less well known and publicized are the environmental benefits of Lean and/or Six Sigma, these are covered in more detail in Section 2.3.

2.2.6 Weaknesses and Limitations of LSS

Considerable research has been undertaken to clarify the disadvantages of Lean (Cusumano 1994) and Six Sigma (Raisinghani el al 2005) as separate approaches but much less has been conducted on the combined methodology of Lean Six Sigma.

Many of the problems experienced with the LSS approach are common to the two separate approaches. These include the usual barriers to implementation as identified by Antony, Escamilla and Caine (2003). These barriers can come from both management and operational employees. There needs to be certain prerequisites such as strong leadership, an open minded workforce and a good communication structure. For the combined approach to be accepted there needs to be clear benefits and these should be clarified during a revised training programme.

When an organisation undertakes a combined LSS approach, it also needs to be mindful of the budgets required for the blended approach as these can be substantial for larger businesses. On the whole training costs for Lean cost less than Six Sigma (Senapati 2004) therefore for a company only experienced in Lean, going to LSS could be very expensive. Therefore before embarking on a combined LSS approach or framework companies need to consider the expertise and awareness of the two approaches existing within the organisation and the chosen project team or teams. Personal experience of LSS implementations has shown that there can be a mix or unbalance of awareness and expertise in Lean and Six Sigma. Therefore there is the possibility that there could be situations where some stakeholders have only used Lean and not Six Sigma and vice versa. This would require a review of the expertise in a given area and additional time and budget may be required to get the team to the same level of knowledge and capability.

Another weakness is the lack of clarity concerning LSS as a structured approach globally. Lean has the 5 Lean principles and Six Sigma has adopted the DMAIC approach, but there is not a specific industry-wide accepted LSS approach. What there is in reality is a mix of tailored approaches developed by LSS organisations, consultancy companies or in-house frameworks. Many companies use the DMAIC and have added Lean tools and techniques at specific stages, whilst others that are more Lean biased send selected employees on Six Sigma training courses Yellow, Green and/or Black Belt levels). In reality, there is considerable variation in the quality of these bespoke approaches in their principles and application (Boyle and Stuart 2007).

This factor combined with the other key points discussed has a considerable impact on the overall sustainability of LSS. This is a known problem for both Lean and Six Sigma as research conducted by companies that have used these proven approaches has identified that 77% of Lean and 76% of Six Sigma implementations fail to achieve the benefits associated with these approaches (Mehta 2004). Regarding the combined use of LSS, less is known about the percentage of failure and the specific reasons, however further clarification of this is sought via the Global Lean Six Sigma Survey discussed in section 5.

Some organisations have added their own Transfer (Kapur 2005) or sustain phase to the LSS methodology in an attempt to improve the sustainability of the approach and improve the ability to hit the projected goals. This, from my own experience, has improved the sustainability of the approach by fully documenting the lessons learnt and transferring best practices to other functions of an organisation.

Another weakness of LSS is the lack of a structured auditing process (Pfeifer, Reissiger and Canales 2004). LSS has a series of phased gates, which could be classed as a method of auditing but this assessment is focused on the project specific. It doesn't clarify how well the tools and techniques that are being deployed are being used in the organisations by function or department. This lack of control and subsequent variation can cause problems and some businesses have subsequently developed their own Lean and/or Six Sigma assessment processes to varying degrees of success, this is covered in further detail in the section 3.2.2.

A further lesser known disadvantage of LSS is that its deployment can result in negative environmental impacts within certain scenarios. This may seem contradictory at first (Venkat and Wakeland 2006) as Lean reduces wastes and Six Sigma reduces variation and scrap, however, this is not necessarily the case. Further clarification of this is demonstrated in Section 2.3.3.

Many of the weaknesses of Lean Six Sigma are commonly known, but some of them described here are less so. However what needs to be determined is the scale of these weaknesses: which do businesses experience more than others? Are there differences between countries and business sector types? This will be deduced from the Global Lean Six Sigma survey results and analysis in Section 5 and 6.

2.3 Environmental/Green LSS

2.3.1 Introduction

Lean Six Sigma (LSS) or Lean and Six Sigma as separate approaches have not been developed to reduce environmental impacts/wastes. However, from personal experience of implementing these types of projects I would argue that in many cases it can be environmentally friendly. Fundamentally by reducing lead times, defects and costs of products or services, there are concomitant and significant environmental gains to be achieved. This section of the literature review will explore this further and also clarify the gains and potential cons relating to the environmental impact of LSS and how it is currently evolving as an approach in its own right.

2.3.2 Environmental Benefits of LSS

From the researcher's perspective, the environmental benefits of LSS implementations occurred as a realization of a Value Stream Mapping workshop in 2004 for a manufacturing company. When analysing the benefits in terms of the 7 Wastes (Transportation, Inventory, Motion, Over Processing, Over Production, Defects and Waiting Time) it suddenly became apparent that there was an additional benefit in addition to the conventional QCD benefits that were being quantified: i.e. a clear environmental benefit that transcended the different waste types.

To clarify this further the benefits have been summarized for each waste type below using specific examples.

Transportation

Reducing the physical distances between processes on the factory floor that require mechanized trucks or handling systems inherently reduces energy consumption and any unwanted emissions from these transport systems. This can also be translated from the internal to the external supply chain and these reductions in transportation distance, frequencies and methods can also reduce environmental emissions as well as financial costs.

Inventory

Many traditional organisations hold excessive levels of inventory within their value chain. There are numerous problems with this strategy including damage/deterioration, storage space requirements, obsolescence, products become lost, and administration and insurance costs. However, LSS and subsequent inventory reduction can reduce these problems significantly. In addition, there are less apparent "Green" benefits. These include reduced heating and lighting through reduced storage quantities and the reduction in some cases of hazardous materials that may require special facilities.

Motion

Unnecessary motion (Poppendieck 2002) where employees move around an organisation in a NVA way is also seen as a waste and this can be attributed to poor workplace design and results in poor ergonomics for the workforce. For small organisations where poor movement of people is present, the environmental impact may be small however for larger companies with bigger footprints there may be a need for transport methods for moving people around different departments or processes. Therefore the reduction of motion waste through more effective layout design could reduce environmental footprint for certain business especially those which have national or international supply chains.

Waiting times

LSS projects use techniques such as line balancing (Jiang, Chen and Wu 2004) and Kanbans (Mitra and Mitrani 1990) between manufacturing processes. Conducting these techniques will improve the flow of the products and significantly reduce the waiting times between processes. Any waiting time is seen as a waste as machines and heating and lighting are still operable. Therefore by reducing the waiting times, a significant positive environmental impact of organisations yearly emissions can result.

Over production

In situations where products have a shelf life, such as in the food sector, producing what the customer wants when they want it will have significant positive effects on the environment. This is a fundamental part of Lean principles where a customer "pull" is utilized rather than a manufacturer "push" into the marketplace. Any waste food from over production will invariably end up in landfill sites. Producing food when the customer wants in the right quantities will also help the food manufacturer save costs on fuels and materials as well as a reduced CO2 footprint.

Over Processing

Through the use of value stream analysis what may seem the "norm" for a process may harbour a high degree of over processing or NVA wastes. This could be in the unnecessary inspection processes, for example, which will result in excessive paperwork and use of testing materials, both of which will be using valuable resources which is not particularly environmentally friendly. Through over processing there will also be an increase in energy consumption through heating and lighting for example. If a process is capable and in control these excessive inspection levels may be able to be reduced thus reducing environmental impacts.

Defects

LSS tools such as Statistical Process control (SPC) are used to reduce unwanted variation of products. This variation could be in terms of dimensional accuracy in relation to a customer specification. Reducing the variation and the number of defects outside the defined specification will result in less scrap or rework. This would therefore save time, costs and would overall lower an organizations CO2 and energy usage. There would also be the environmental benefit of less disposal costs of any scrap or defective products.

A good case study of combining the benefits of Lean and the Environment can be seen from EPA's (Ross and Associates 2006) work with Aerospace organisation Lockheed Martin. The Manassas plant in the USA used Lean thinking on its chemical and waste management processes and so found that large amounts of chemicals were being sent to the hazardous waste stream without being used. Just in time principles (JIT) were therefore implemented for their chemical management system. This comprised of delivering the chemicals in the right quantities based on real time demand. These chemicals were delivered at an appropriate frequency, which helped reduce inventories and reduced storage costs and eliminated chemicals going beyond their shelf life.

A further example can be seen from a case study in the construction industry where Lean can provide significant environmental benefits. Peng and Pheng (2011) found that the deployment of a structured Lean approach could reduce carbon emissions and non-value added wastages. These wastes were identified using VSM techniques and subsequently JIT was used for the delivery of the precast concrete columns.

Olsen and Brady (2009) found that the use of "Green Sigma", a 5 step approach developed by IBM could be used to significantly reduce carbon emissions in a case study for a large electronic-manufacturing warehouse facility. For example DOE was used to optimise the parameters of the environmental control heating process which provided reductions of 10-15% of total energy use which translate to a significant CO_2 reduction of around 100-150 tonnes per year.

2.3.3 Environmental disadvantages of LSS

As described earlier in the section, Lean Six Sigma was not developed with environmental impact reduction in mind and although some organisations are researching how Lean and/or Six Sigma can be combined with environmental management processes, very little has been done to investigate the negative environmental impact of Lean Six Sigma.

One exception is that of Venkat and Wakeland (2006) who discussed the negative impact of Lean and as LSS is a combined approach, their findings would still apply. Their research demonstrated that by following Lean principles for a supply chain (transport and storage) of ready meals for a food manufacturer the overall emissions in certain circumstances were higher than for a more traditional supply chain. Reducing inventories of cold stored products saved costs but meant that more frequent deliveries were required of the product, which in turn increased transport emissions. The study did recognise however that its focus was on carbon dioxide emissions and did not cover other environmental wastes. As a result, its findings are not conclusive and further research is required.

Another negative aspect of Lean Six Sigma comes from my personal experience of the approach. A key tool used in the approach is design of experiments (DOE). This particular tool is used to optimise processes by changing the inputs to a process to influence the output. To understand this in simplified terms, in the case where the desired output is miles per gallon (MPG) for a car, the inputs that could be changed to influence the MPG include the tyre pressure, the number of passengers (additional weight), or the driver of the car. Changing the combination of these inputs by conducting a number of experiments means it is possible to determine the optimal settings of each input to achieve the best output.

The DOE tool is used by numerous industry sectors to optimise products and processes but is not always environmentally friendly. One popular area of application is the chemical sector where it is used to optimise the raw materials required. By changing the inputs it is possible to achieve a better product, but in order to do so, the ingredient that is increased in weight or volume could be one which is bad for the environment. This is a key area where Lean Six Sigma and more specifically some of the tools and techniques used do not consider the environmental consequences. This does raise the debate of whether Lean Six Sigma tools and the approach would benefit from tailored development towards environmental management.

2.3.4 Evolution of Environmental LSS methodologies

Finding out existing research in the area of Lean Six Sigma and its environmental impact has yielded some interesting results. One key conclusion, is that although there is widespread information about Lean, Six Sigma, Lean Six Sigma and its benefits including waste reduction (Arnheiter and Maleyeff 2005) , these are not widely viewed in environmental terms but are seen as more akin to the working environment (Bamber and Dale 2000).

Of the publications found that are relevant to environmental impact, these are predominantly associated with Lean, not Lean Six Sigma. As a combined approach LSS is a much more powerful as a technique and is now appears to be superseding Lean and Six Sigma as individual approaches (Global LSS Survey aims to evaluate this claim this in Section 5), as demonstrated by the likes of companies such as Lockheed Martin, Caterpillar, Textron, Honeywell and General Electric (Mikytuck 2006).

With reference to Lean, the ideas of Sawhney et al (2007) are a case in point. Within the metal cutting supply chain, they discuss "however, less obvious is the impact of lean on the environmental performance of the manufacturer". They proposed a methodology to examine the relationship between

Lean principles and their overall environmental impacts. Further evidence of Lean and its associated benefits for the environment are highlighted by Vais et al (2006) who examined how to use Lean and Green production techniques to improve industrial compliance with the effluent regulations at a Romanian tissue paper mill. This resulted in an 87% reduction in wastewater discharge.

Regarding Six Sigma, there is again little in the way of recognition of the combined benefits with the environment. However, Gupta and Nukala (2006) recognise that rapid technological developments and the growing desire of customers to acquire the latest technology have led to a new environmental problem "waste". They propose that "as a result, both consumer and government concerns for the environment are driving many original equipment manufacturers (OEM) to engage in additional series of activities stemming from the reverse supply chain". Using the Six Sigma method devised by Motorola, Nukala explores how to improve the synchronisation of the closed loop supply chain.

There is limited evidence that Lean and Environmental consultancy have been combined into a working framework. Ball and Maleyeff (2003) discuss the applicability of Lean management principles to improve business operations in an environmental consulting company. They present the principles "in a manner that environmental managers may use as a model to achieve specific operational goals". Examples illustrate how Lean concepts were applied at two environmental consulting firms. This however has not resulted in full adoption of the process; the reasons for this need to be clarified.

There is recent recognition by Venkat (2006) regarding the potentially negative side of Lean, but this does not expand to Lean Six Sigma. This argument is backed up by Womack (2003) who questions moving operations to the East when this can be environmentally damaging due to the increased transportation.

Of the research conducted so far in the area of Lean and the Environment the most detailed work undertaken would appear to be that of the Environmental Protection Agency (EPA) in the USA. The EPA has developed a Lean and Environment toolkit (Ross and Associates 2006). This toolkit in conjunction with various business partners has been developed by combining Lean tools and techniques with principles of environmental management. Its purpose is to enable Lean practitioners to improve both the business and environmental performance of an organization. It has a structured approach using some of the key Lean tools but these have been further tailored in environmental terms. The toolkit itself is very logical, easy to understand and implement within just about any business. The EPA has a range of business cases to back up the argument (as discussed in the previous section). However, the work conducted by the EPA is predominantly focused on Lean and the Environment and not Environmental LSS.

IBM has also developed an approach in 2008 called Green Sigma (Bachour and Chasteen 2010). This methodology is part of a series on carbon management and it identifies the increasing on pressures of increasing legislation on organisations and rising energy costs effecting businesses. It utilises a number of Key Performance Indicators (KPI's) such as logistics, carbon foot-printing and energy usage. IBM has adapted certain Lean tools such value stream mapping into carbon value stream mapping and the voice of the customer into the voice of the environment.

Subsequently in 2009, IBM announced it had brought together some of the major global energy players to become involved in their Green Sigma approach. The coalition's charter members include Johnson Controls, Honeywell, ABB, Eaton, ESS, Siemens, Schneider Electric, and Cisco. Together this partnership have plans to make their equipment and services work with IBM's Green Sigma offering, which is aimed at using sensors and controls to fine-tune corporate energy use.

IBM has been working with a number of these companies for some time on integrating energy management and it's the aim of the new coalition to add carbon emissions and water usage along with the additional goal of putting it all in a framework that lets senior management track usage in as close to real time as possible

The international consulting organisation Deloitte has developed their Green Lean Six Sigma process (Branch 2009). Their aim is broaden the LSS approach to improve business performance through three key factors. Firstly, through effective governance of the improvement projects both from the top down via leader's prioritization of key environmental drivers and bottom up through an effective ideas and suggestion process.

Secondly, through effective measures that is linked to CTQ's (Critical to Quality) factors. They recommend that companies define what sustainability measures are most important and to drill down the 1st, 2nd and 3rd tiers of usage for resources such as lighting efficiency for offices for example.

Thirdly, Deloitte suggest adding environmental awareness training to traditional Yellow, Green and Black Belt courses to training programmes to increase acceptance of reducing environmental wastes for LSS projects. The overall approach however seems to concentrate on using Lean predominantly alongside the DMAIC framework with environmental awareness to drive environmental improvement without the use of specially developed or tailored Green LSS tools and techniques.

Another company who are forging forward are Renault-Nissan who have developed via their consulting function their own Green Lean® process and have registered the name, however many other organisations use Green Lean as a moniker for conferences and papers. There is little research material available on the approach, how well developed it is, associated case studies and quantifiable benefits.

The evolution of Green Lean and/or Six Sigma has seen a number of dedicated conferences in recent years. The inaugural Green Sigma Conference was held in Chicago in 2009 which the researcher attended and presented a research paper on a development and testing of a Green 5S Sustainability Audit methodology which is discussed in Section 8. This conference saw numerous paper presentations on how Lean and or Six Sigma have been used to gain significant environmental benefits.

Since then there have been numerous especially dedicated Green Lean and/ Six conferences. In 2012 there are at least three international events being held including the USA, UK and Germany, which would suggest that Environmental LSS as an approach is growing in popularity.

The driver towards environmental LSS however seems to be coming more from the LSS community rather than the Environmental community, the researcher has attended and presented two large international environmental conferences (International Conference on Environmental, Cultural, Economic and Social Sustainability 2009 and 2010) and knowledge of Environmental or Green LSS is very limited.

Overall positive effects of Lean Six Sigma has been identified in a limited number of fields, however there appears to be very little research on its negative impact on the environment and, more importantly, how this could be overcome via an integrated framework.

Another unknown factor is which Lean and/or Sigma tools and techniques are most appropriate to gain environmental benefits and which are not? There are a high number of tools and techniques available on LSS projects; for example the researcher has used around 150 tools and techniques in the last 20 years, of these around 30-40 are used on a regular basis on LSS projects within industry. Which of these tools and techniques should be developed further into tailored environmental improvement methods? In order to answer these questions the Global LSS survey is required that is discussed in Section 5.

Overall, it can be concluded from this literature review that Environmental or Green LSS is still immature as an approach in terms of research and application, but it looks set to grow and mature over the few years as drivers for environmental change increase for businesses and communities.

2.4 Environmental Management Systems (EMS)

2.4.1 Introduction

LSS as discussed earlier has not been developed to reduce environmental wastes and resulting footprints. However, as we have established it can benefit the environment and is being developed into bespoke Green LSS approaches by some organisations, this section will examine contemporary EMS systems and their potential compatibility with LSS.

ISO14000 is the most commonly deployed EMS globally. It is used by virtually every industry sector and the purpose of this section of the literature review is to explore whether the ISO14000 series and the ISO14001 standard in particular has been beneficial as a framework for continual environmental improvement within organisations. Therefore we will examine ISO14001 in more detail and clarify its current strengths and limitations. This review will also outline synergies and opportunities for improvement when aligned to LSS to reduce environmental impacts.

2.4.2 Background to EMS

An Environmental Management System (EMS) is a structured framework for managing an organisation's significant environmental aspects and impacts. Some organisations have adopted the framework specified in national or international standards that set out the requirements of an EMS and have had their systems externally assessed and certified against these. Other organisations have developed their EMS in a more informal way. Whatever approach has been adopted, the elements of the EMS framework will largely be the same.

There are various EMS approaches including EMAS, BS7750, BS8555 but the global leader in terms of deployment and acceptance is ISO14001 and there are no indications that this will change for the near future. The International Standards Organisation (ISO) defines the 14001 (Epstein and Roy 1998) EMS as "*the part of the overall management systems that includes organisational structure, planning activities, responsibilities, practices, procedure and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy*".

The basic structure of an EMS process is depicted in Figure 2.3:

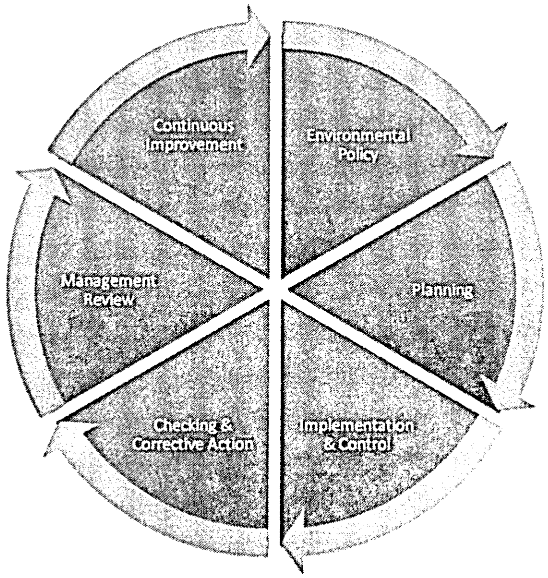


Figure 2.3: The EMS Process Structure

2.4.3 Evolution of ISO14001

The origins of the International Standards Organisation (ISO) date back to 1947 (Block 1997).The aim of ISO was to develop and introduce international standards for different industry sectors. This standardisation was designed to aid companies trading across different nations to increase trade, quality, and productivity and reduce costs of goods and services. ISO has since developed over 3000 technical and non-standards and this led to their most famous implemented series of standards ISO9000.

ISO14000 has been in existence since 1996 (Edwards 2004) and was updated in 2004 with a revised and extended version. The initial concept of the ISO 14000 environment system standards was prepared in June of 1992 year in Rio de Janiero (Evers 1997) after ISO recognised the need for an international standard for environmental management. In 1993, ISO established one technique committee, which was attended by 50 different country representatives, to prepare an international environment management system. ISO14000 evolved in a similar way to ISO 9000 in that the origins of ISO 9000 were based on BS5750, and so the foundations of ISO14000 can be traced back to

BS7750. Using the referenced source information described above the evolution of ISO14000 was created by the author and is depicted in Figure 2.4 below:

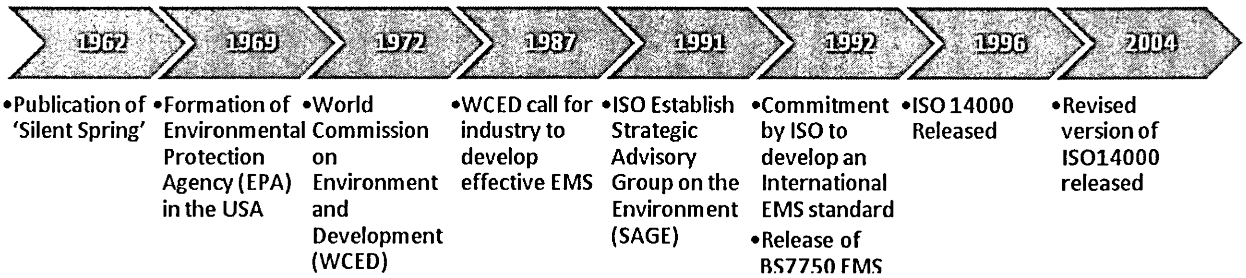


Figure 2.4: Evolution of ISO14000

Initially, acceptance of ISO14000 was stronger within the Asia Pacific Economic Cooperation (APEC) than elsewhere. This organisation comprised of 18 countries, but the acceptance gathered pace quickly. By the beginning of 2000 over 10,000 ISO registrations had been completed, and by 2002 this was estimated to have exceeded 150,000 registrations (Grier 2002). Its popularity has been particularly high in the USA, UK and Germany within manufacturing sectors.

ISO 14000 consists of a series of elements, and ISO14001 is the dominant feature and actual standard of the series (Tibor and Feldman 1995). It specifies a framework of control for an EMS against which an organization can be certified by a third party.

Other elements of the series include:

- ISO 14004 - guidance on the development and implementation of environmental management systems
- ISO 14010 - general principles of environmental auditing (now superseded by ISO 19011)
- ISO 14011 - specific guidance on audit an environmental management system (now superseded by ISO 19011)

- ISO 14012 - guidance on qualification criteria for environmental auditors and lead auditors (now superseded by ISO 19011)
- ISO 14013/5 - audit program review and assessment material.
- ISO 14020 - labeling issues
- ISO 14030 - guidance on performance targets and monitoring within an Environmental Management System
- ISO 14040+ covers life cycle issues

2.4.4 ISO14001 Framework

ISO14001 is similar to ISO9001 in that it is a framework consisting of process standards, not performance standards. They both promote management systems that focus on prevention rather than corrective action.

The intention of ISO 14001 is to provide organisations of any sector, size, structure and demographic location with the assistance and framework structure that will help prevent or reduce environmental impacts as a result of an organizations processes, products and/or services.

Environmental Policy

Initially, an organisation's senior management must develop its environmental policy. The policy itself must be appropriate to the organisation itself in terms of size, scale and any environmental impacts that it may have. The policy should contain three commitments (Drury 2009): to prevent pollutions; comply with topical regulations and legislation; and finally to aim to continually improve and not stagnate. The framework of the policy should also be communicated to employees and be available to the public, though this is not a formal requirement. The policy should also be documented, implemented within the workplace, reviewed and maintained by designated stakeholders within the company.

Planning

The second element of the framework is the planning section, which is required in order to fulfil the environmental policy. The plan will enable the key internal stakeholders to deliver the policy and will answer the question of "How do we make it happen?"

The key elements of the plan consist initially of identifying the environmental aspects and impacts of the organisation. Every organisation is different so this stage it is vitally important to clarify the organisation's own fingerprint in terms of environmental aspects and impacts.

Environmental aspects are described in clause 4.3.1 of ISO14001 (Goetsch and Davis 2001) which states that "*an organisation should establish and maintain the environmental aspects of its activities, product or service that it can control and over which it can be expected to have an influence, in order to determine those which have or can have significant impacts on the environment*". Examples of environmental aspects and impacts (Roberts and Robinson 1998) are shown in Figure 2.5.

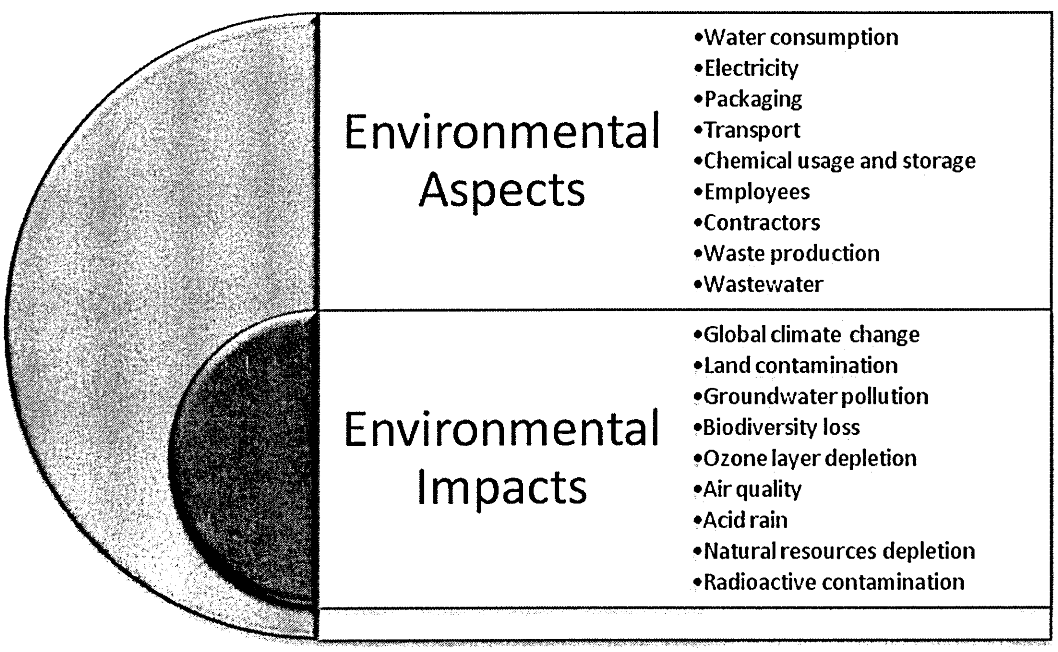


Figure 2.5: Environmental Aspects and Impacts

The associated environmental impacts can be defined as the environmental changes (positive or negative) that occur due to organisations activities, products and services. Examples of these are also shown Figure 2.5.

Next the planning process requires that the organisation documents legislation that is relevant to their business. This includes acts and regulations, industry codes of practice and agreements with local authorities. This may be easy for larger organisations that have environmental employees however for SMEs this may be more difficult.

The plan should also include objectives and targets which are measurable by the organisation so that status and progress can be ascertained. Finally the plan should contain an environmental management programme.

Implementation and control

The third element of ISO14001 EMS framework concentrates on the "doing" aspect of the standard. The structure of the framework and roles and responsibilities are defined at this stage. Communications and documentation methods are then defined by the team, coupled with structured training plans and competence records. A register of the environmental aspects and impacts is developed within this stage and actions are prioritized in order of importance.

Checking and Corrective Action

The penultimate phase of the ISO14001 EMS Framework monitors and measure progress in relation to the plan in line with the metrics defined earlier. Any environmental non-conformances should be identified and corrective action taken where possible by the appropriate stakeholder. Internal audits should be scheduled, planned and conducted.

Management Review

The final phase of the ISO14001 EMS framework is comprised of the scheduled collection and review of information to senior management. This review is performed to confirm whether the EMS is still suitable for the organisation and to demonstrate its effectiveness. The results from the review including benefits and the resulting lessons learnt are also useful as part of developing continuous improvement culture within an organisation. This is sometimes defined as the adjustment phase of the Plan-Do-Check-Adjust (PDCA) cycle (Woodward 2007).

2.4.5 Benefits of ISO14001

ISO14001 and its benefits to organisations are well researched. The most immediate benefits of the approach is that its correct use will lead to more efficient use of key energy types and materials (Pinero and Mason 1998). This in turn will lead to a reduction in the waste outputs that an organisation will produce and the consequent reduction of costs (Holland 2006).

Another key benefit of ISO14001 is that it a recognised international standard and ISO itself is well respected in general. Consumers in general who have knowledge and awareness of ISO14001 may feel assured by the standard and its ethical intentions.

ISO14001 also gives an organisation the mandate to control its environmental aspects and impacts on its own processes, products, and services. It could be said that in many circumstances nobody knows their business and resulting wastes better than the organisations themselves. This allows the internal experts to control the situation not some outside body who does not understand their business and it intricacies.

These are the obvious benefits but there are many more business improvements that a company can expect through a thoughtfully planned implementation of ISO14001. Legally a company will reduce its risk of prosecution through poor environmental management practices and also the risk of insurance claims. This could also reduce resulting insurance premiums due to the reduced risk and resulting claims that will also improve relations with financial institutions.

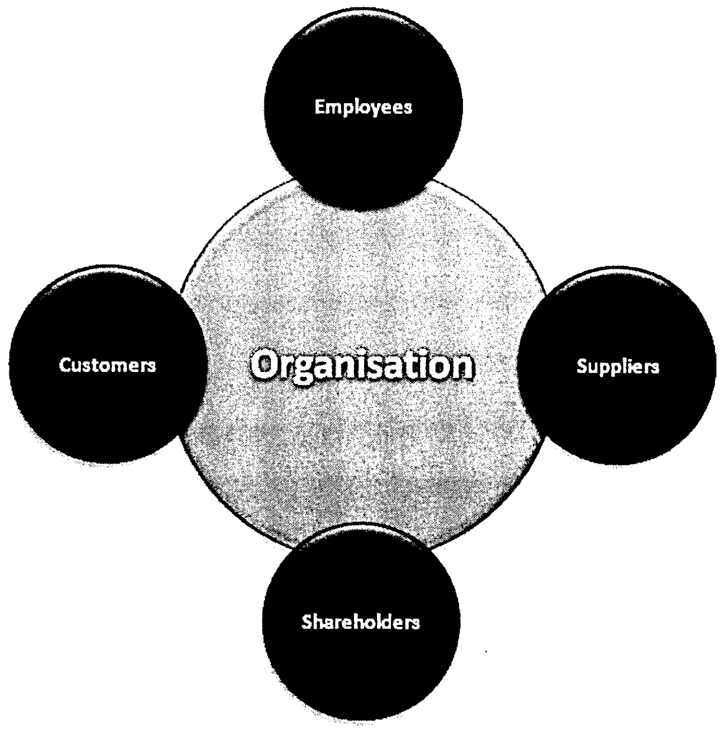


Figure 2.6: Key ISO 14001 Stakeholders

To internal or external shareholders willing to invest in organizations, those who use ISO14001 will be seen to be more ethical and potentially attractive. However as with the use of ISO14001 there is no guarantee of environmental success (refer to weaknesses of ISO14001) this can be a bit misleading to shareholders.

Organizations may also seek to achieve ISO14001 accreditation as a means to gain or retain their market share within a particular industry sector. It could be deemed that the adoption of ISO14001 would give an organisation a green corporate image, a company which cares about their local, national and global environment. This would no doubt concern a certain percentage of the four types of stakeholders (Strachan 1998) depicted in Figure 2.6.

The adoption of ISO14001 would no doubt be of assistance in terms of relationships with local government who are becoming increasingly keen on suppliers having 'green' credentials and some even specify this within tender documents for new business.

Internal stakeholders (namely employees) may also gain motivation and pride in their organisation through the practice of ISO14001. It would provide environmental awareness for employees and provide them with a framework to assist in reaching company targets. The pride and knowledge gained could subsequently be passed to others in the community.

For SME's, ISO14001 could provide benefits to their relationships with external suppliers. Those which are already environmentally aware may wish to conduct business with an SME who uses ISO14001 over one which does not. For larger organisations these benefits can spread to both internal suppliers within their own organizations and external supplier bases.

2.4.6 Weaknesses of ISO14001

ISO14001 has many good intentions but it has several flaws that reduce its positive environmental impact and this leads to variation and inconsistency in its success rate within organisations. These weaknesses could reduce its sustainability for the long term.

Awareness of ISO14001

There is a general lack of awareness in two key areas; these are within SME type organisations and the general public. Awareness of ISO14001 is more widespread within larger companies but much less so within smaller businesses. Research conducted in Canada (Johansson 2003) shows very limited awareness of ISO14001. The Canadian Federation of Independent Business (CFIB) conducted a survey which has a large response of 4,322 organisations. The CFIB represents the critical mass of Canadian business over 100,000. This showed that 73% had never heard of ISO14001.

ISO14001 is a process designed for companies not for the general public; however the lack of engagement is a major omission. Its integration with local communities is a missed opportunity to gain support for the programme. It would also put more pressure on organisations to embrace ISO14001 if the general public had awareness of it and requested it for their products and services.

Lack of Transparency

The only element of ISO14001 which is made public is the environmental policy statement. The other elements including targets and audits are totally private unless a company wishes to make them public (Block 1997).

A key difference between ISO14001 and another EMS standard BS7750 is the omission of an annual environmental performance statement. This lack of transparency is a major disadvantage of ISO14001 as there is no requirement to make public any information about an organisation's environmental impact. A company could do so voluntarily if it so wished, but it may not think this prudent in case it placed them in a poor light.

Also EMAS requires that a company makes its environmental objectives are made public (Wenk 2005), ISO14001 does not. Again this lack of transparency does not benefit ISO14001 and could be one of the causes of the lack of public awareness of ISO14001 and subsequently could affect people's trust in the standard.

Surely ISO would prefer consumers to make informed decisions about who they should procure products and services from, but this lack of transparency means companies that are less legitimate in their implementation of ISO14001 stand to benefit most. Indeed it could be argued that consumers may do business with companies who are behaving in an environmentally irresponsible and dangerous fashion without having any knowledge of the fact.

Cost of ISO14001 Implementation & Certification

Any business large or small should evaluate the benefits of certification against the costs associated with it and this includes the intangible as well as tangible costs. Many organisations do not think this through before embarking on the journey of certification.

The costs and time deployed to gain certification can vary dramatically depending on the size of an organisation and the demographics of the business and subsequent EMS. Much depends on whether a company conducts its business locally or on sites nationally and/or globally and so organisational structure may play a large part in terms of cost. Each time certification is sought for a business, it must comply with the laws within that demographic area, national and international ISO14001 certification. So this can be extremely costly. Costs including implementation and certification for large businesses can be high for example a company with 2000 employees can expect to pay in excess of £200k (Van Der Veldt 1997). This depends largely on the type of business that an organisation may be in or the legislation within a given area. A company should consider both internal and external costs.

Internal costs include the costs for new equipment for taken measurements or the modification of existing equipment. There will also be budgets required for training employees and in addition, employee time for planning and implementation of the ISO14001 EMS. There may also be additional costs for systems to record environmental data and the communication of this data these costs are estimated to take up 90% of the overall budget required (Van Der Veldt 1997).

External costs include the services of an external 3rd party auditor for registration and annual audits. A legal representative to check compliance with environmental legislation may also be required in relation to the demographics of their products and/or services. These costs may make it difficult for SME type organisations to explore certain markets, which is restrictive and in some ways could be construed as unfair.

Problem Solving Ability

One of the key objectives of ISO14001 is to reduce the impact an organisation's processes, products and services have on the environment. Once a company understands its environmental aspects and impacts, it may find that many of the environmental improvements do not require complex problem solving techniques (e.g. use of energy saving bulbs, recycling paper etc.). However, certain problems may not be obvious or easy to solve and ISO14001 does not provide the tools and techniques to make the necessary improvements sought from their self-imposed targets.

Many environmental problems may need structured statistical analysis in order to identify root causes. Processes may exhibit high degrees of variation which demonstrate being out of control and many companies may not have the internal capability to solve these complex problems.

There is very limited evidence which shows that organisations that use ISO14001 (Miller, Pawloski and Standridge, 2010) are combining it or using it alongside business improvement approaches such as LSS (mainly Lean) to gain the capability to increase its chances of solving complex problems. However the scale of this combination is unknown and it's hoped to establish this scale through the Global LSS Survey in Section 5.

Voluntary Process

Like LSS, the ISO14001 process is entirely a standard that companies can choose to employ if they so choose. Pressure may exist on companies to achieve certification but this is usually due to pressure from stakeholders such as customers, shareholder and external suppliers. The pressure may also exist from local government to achieve ISO14001. However, companies not wishing to engage in the process are not automatically forced to do so. This is of concern if it is wished to monitor companies who may be causing excessive environmental impacts. However, it could be viewed that with increasing national legislation such as the climate change bill (CCB) in the UK (Ockwell, Whitmarsh and O'Neill 2009); these companies may be forced to implement ISO14001 whether they want to are not.

Internal Goal and Target Setting

Companies aiming for ISO14001 certification set their own goals and targets, which can be viewed in both positive and negative terms. The positives are that the company knows its own capabilities and limitations and therefore should be able to set it realistic goals to achieve using the ISO14001 framework. However, this could also be exploited by the company by setting itself easy goals to achieve and subsequently stating to stakeholders that it is ISO14001 certified without really deserving this status. Having ISO14001 could appear on the surface to customers may make a company look very ethical however they may have improved marginally. This can make the process very misleading and exploitative for customers and shareholders alike.

It would be useful if the process allowed open and transparent benchmarking between comparative organizations, this would help ensure that targets were more realistic from a sector to sector basis.

No Performance Standard

A key omission of ISO14000 is that it does not establish performance standards (Hanson 1998) and it doesn't measure environmental performance. What it does do is assist organisations in reaching a target of increased performance; ISO14001 is more concerned about processes than the actual outcomes.

There is little linkage between ISO14001 and the various nations that develop national and international laws and legislation. Also a company could, if it so wished, relocate to less restrictive nations and become an ISO14001 certified organisation. The effectiveness of the standard in this situation would therefore be minimal and surely depicts a poor image of ISO14001 to customers, suppliers and shareholders.

Self-Implementation and Management

Implementing ISO14001 is a self-managed process, and therefore its success depends largely on the management commitment present within the organisation. Many organisations may fail to achieve the goals of ISO14001 due to a management structure's lack of awareness of the commitment required in terms of time and money. Managers may set unrealistic or extra lenient goals to portray their organisation in a better light than it should, ISO 14001 does not protect customers and other stakeholders from dubious managers who may have a different agenda for their reasons for achieving ISO14001 certification.

2.4.7 Integration of ISO 14001 with LSS

Examining the strengths and weaknesses of ISO14001 clarifies certain benefits that could be gained from combining this approach with LSS. In terms of problem solving ability LSS is incredibly strong in this area from the use of techniques such as FMEA and Fishbone diagrams. The use of these simple and easy to use tools and techniques on identifying the root cause of problems would be invaluable for a selected project. Because of their simplicity, environmental managers and teams would quickly be able to deploy them within their organisation.

For more complex problems, LSS statistical tools and techniques through the use of Minitab may be more suitable. Through the use of techniques such as DOE it may be possible to optimise certain processes and their inputs to garner reduced levels of harmful chemicals for example. Or it may be possible to reduce highly valuable raw materials whilst still achieving an acceptable product/service in line with the customer requirements.

Many organisations from SME's through to larger organisations may also have both the LSS and EMS capability available internally therefore the knowledge and skill already exist within the business. These businesses would not have to heavily invest in training of employees if the skills already exist. Pojasek (2008) argued that for this to succeed there need to be full involvement with employees at all levels of the business for the setting of objectives and goals. One of LSS strengths is its ability to bring together all stakeholder levels when implemented and communicated properly with an organisation and this would benefit improvement frameworks such as ISO 14001.

Many view ISO 14001 as a preventative framework (Pojasek 2008), however, LSS can also add to this through the use of tools such as Poke Yoke. By lowering the risk of a non-conformance this in turn would significantly reduce the probability of risks becoming harmful and unnecessary environmental impacts.

Research conducted by Bergmiller and McCright (2009) emphasizes the synergy between Lean (not Six Sigma) and EMS processes such as ISO 14001. They highlight that the companies that use elements of EMS systems in their Lean programmes have stronger Lean results than those that do not include "green" elements. They also show that there is a positive correlation to cost reduction with significant confidence ($p<0.001$). Another important point that they identify is that by combining Lean and EMS practices it is possible to optimise human resources more effectively.

Recent explorative research conducted by Puvanasvaran, Kerk, and Muhamad (2011) using a small sample size of 15 respondents identified that 98% felt that adding Lean would add value to EMS processes and 97% replied that it would improve productivity. They also found that respondents felt that combining Lean and EMS would provide more sustainable growth and streamlined work processes. The main barriers were identified as being inadequate leadership and implementation within the business. However they recognise that this research is very limited in size and scope and more detailed research is required in the future to realise any firm conclusions and recommendations.

In this section of the review we have clarified there are significant benefits to combining LSS with EMS practices. However, this argument has been based on the researcher's own experience combined with limited research described previously. This is a growth area for research as the majority of the review material being published over the last 5 years as identified in Section 2.3.4. Therefore it is important to gauge what the Global LSS community think to this as a concept and across all stakeholder levels and business sector types. Through the use of the Global LSS survey (section 5) the aim will be to clarify and answer these questions in order to develop the proposed ELSSSA framework and associated tools / techniques.

2.5 Environmental Legislation

2.5.1 Introduction

Whilst EMS approaches are voluntary (unless stakeholder pressure proves otherwise), environmental legislation be it global, national or local is not. Therefore, businesses face increasing pressures to comply with environmental legislation or they risk not being able to supply their products and/or services to certain countries and market sectors.

This section of the literature review will outline the current and future environmental legislation for the UK and Global climate change treaties. It will clarify what this means for SME's through to larger PLC type organisations in terms of increasing environmental targets. Finally we will examine how LSS could help businesses with the challenge of meeting these legislation requirements for the future.

2.5.2 UK - Climate Change Act (CCA)

The Climate Change Act (CCA) was defined in 2008 and subsequently signed off by the Secretary of State of the Labour party Ed Miliband (Now its Leader) in April 2009. When the CCA was signed off, the UK was unique in being the only global country to have introduced a long-term legally binding framework to tackle the increasing risks of climate change. In addition, the Committee on Climate Change (CCC) was set up as an independent body as part of the Act.

The focus of the CCA is that it requires that emissions are reduced by at least 80% by 2050, compared to 1990 levels. The 2050 target was raised to 80% from the original 60% following recommendations set out by the CCC in 2008.

Another feature of the CCA is that it introduces legally binding carbon budgets. These budgets will set limits on the levels of greenhouse gases that can be emitted into the atmosphere. The CCC's first report "Building a low-carbon economy" advises on the level of these budgets for the first three five year periods. Other key responsibilities of the CCC will be to monitor and report back to Parliament on an annual basis on progress made by Government in meeting carbon budgets.

Since the CCA sign off there has been on-going debate since the general election in and change of power to the Conservative Party in 2010 regarding the Climate Change Act. A statement released on March 21st 2012 stated however that it will not be altered despite the Chancellor George Osborne's comments about how expensive 'green' regulations and how this is impacting the UK economy.

In the last 12-months there has been a detailed review (Mason 2012) into reducing the red tape associated with environmental legislation which is quoted as costing the UK up to £18bn a year. However, the Energy Secretary Ed Davey has stated that he would not be looking to change the Climate Change Act.

There has been publicised concern form George Osborne about "the combined impact of the green policies adopted not just in Britain, but also by the European Union". And in addition he has implied that more 'green tape' could mean that "businesses will fail, jobs will be lost, and our country will be poorer".

In spite of this however Davey has called the Climate Change Act "essential legislation" and said it should remain untouched, however this could still change.

Very few have the link between the CCA and the opportunity that LSS offers itself to businesses. Many organisations already have their own internal LSS capability, however, it does not appear to be on the radar to use these existing skills and knowledge to reduce environmental wastes and conserve valuable resources.

The only review material found was that of Olson and Brady (2009) who recognises that in terms of drivers for regulatory and legislative change this has been lacking but the CCA may change this and that approaches such as IBM's "Green Sigma" may help to facilitate this.

Many larger organisations including PLCs have the internal resources including having their own environmental departments to be able to meet these increasing environmental targets set. Many SMEs do not have this capability but many already use Lean Six Sigma. Therefore as clarified in section 2.3.4, there is untapped potential to utilise specially developed LSS approaches to use less valuable resources and therefore help contribute to the reduction of carbon emissions and go some way to achieving the targets.

2.5.3 Global Climate Change Treaties

The first climate change agreement was the Kyoto Protocol and this was defined and agreed by the United Nations Framework Convention on Climate Change (UNFCCC). The aim of this environmental treaty was achieve "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Hoffert et al 1998)

The original Protocol was adopted in Kyoto Japan on December 11th 1997 but it did not actually come into force until 2005. The USA is famously the only one of 191 member states which did not ratify the agreement, and in December 2011 Canada renounced the protocol as well.

Of the 191 member states, 37 countries agreed to commit to the reduction of 4 types of greenhouse gases (GHG) and 2 types of gases. These countries dubbed as Annex 1 would reduce these by 5.2% over the period 2008-12. This would be relative to the benchmark levels that were being measured back in 1990. These targets however were voluntary for the Annex 1 countries and not legally binding (Bohringer and Vogt 2003).

In terms of the current status of Global Climate Change legislation in December 2011 the United Nations Climate change conference was held in Durban, South Africa. At this event the objective was to set a new treaty to limit global carbon emissions. At the conference all the countries agreed to a legally binding set of targets which will be prepared by 2015 and come into effect by 2020.

This agreement which is now referred to as the "Durban platform" (Stavins 2012) is the first time that developing countries such as India and China have agreed to sign up. Also of significance, the USA who formerly would not sign up to the Kyoto Protocol is also agreeing to this new legislation. Another key difference with this agreement over the Kyoto Protocol is that it will be legally binding and not voluntary as are the current targets until 2020.

Another important aspect of the agreement will be the creation of the Green Climate Fund (GCF), which will see US$100bn annually distributed to developing countries. The aim is to use this money to help these countries adapt to the changes in environmental practices to reduce the impacts.

Many see this agreement as a big step forward including the United Nations Climate Chief Christina Figueres who said "I salute the countries who made this agreement. They have all laid aside some cherished objectives of their own to meet a common purpose – a long-term solution to climate change".

Regarding the link between Global Climate Change protocols or treaties and the use of LSS to help reduce environmental impacts this review identifies that a limited number of authors have recognized this synergy. Olson (2009) establishes that companies such as IBM are using "Green Sigma" to achieve energy savings of approximately 20% thereby contributing to the target set within the 1997 Kyoto Protocol targets.

Research within the construction industry sector conducted by Peng and Pheng (2011) clarified the link between the Kyoto Protocol and the use of Lean to help reduce environmental impacts. It examines how Lean thinking can be used in construction sites on precast concrete products to achieve low carbon erection. However, this research is very specific to a single industry sector and does not examine Six Sigma although a link is established all the same.

Further evidence of the link between Lean and Global legislation can be seen from Mason, Nieuwenhuis and Simons (2008) who research aim is to move from silo ecological supply chain to a Green and Lean Supply Chain. Their research recognizes the use of Lean and Green and the use of these approaches to assist legislation such as the Kyoto Protocol in countries where they have signed up to the agreement.

Shahrbabaki (2010) recognizes the growth of Green and Lean and how it can be used to target widely accepted targets such as the Kyoto Protocol. This research focuses on the use of environmental Value Stream Mapping (EVSM) and how it can be used to reduce energy usage within a production environment.

There is currently no link cited between Green LSS and the latest "Durban agreement", however this is due to the latest agreement being outlined in December 2011 and the actual targets won't be formally agreed until 2015 and operational in 2020.

Overall recognition however of LSS and its ability to assist companies in meeting these current and future global legislation requirements is very limited. There are individual cases predominantly using Lean where a link is made but the big picture or vision in terms of the impact that an approach that LSS could have globally for all types of businesses is lacking.

SME type businesses who may not have the resources will struggle to manage to meet these increasing targets over the next 30 years due to their lack of environmental knowledge and expertise that a larger organisation may possess. This lack of awareness that LSS and its tailored environmental application could offer would appear to be lacking in focus and intent at the present moment time in the majority of organisations.

2.6 Literature Review Summary

In this section it has been highlighted how LSS has evolved from its origins in manufacturing in the developed world to the globally recognized business improvement approach that can be applied in virtually all industry types.

In addition to clarifying the current state of LSS and its more recent use to garner environmental or green benefits there are several opportunities which have been identified that require further research through this thesis.

- Very little is known about the specific reasons for the failed sustainability of conventional LSS as a combined approach within global businesses by sector and continent.
- There is very limited evidence of organisations using structured auditing methods to gauge where and why conventional LSS is either successful or failing within their businesses, even less so from an environmental perspective.
- LSS is being used to a certain degree (scale unknown) to provide environmental benefits to businesses, but much less is understood about the negative environmental impact that it can have.
- Integrated assessment frameworks or approaches for specifically gaining environmental benefits through the use of a tailored LSS approach are very rare and associated with large organisations and not developed for SME type organisations or less developed countries.
- Organisations are developing their own Green Lean and Six Sigma approaches however demand and knowledge for these approaches is unknown.
- The specific Environmental LSS tools and techniques deemed appropriate by LSS users for use in industry to gain environmental benefits is unknown.
- Very limited levels of research currently identify that EMS approaches such as ISO14001 have a number of weaknesses that could be addressed through the integration of LSS approach.
- Scale of integration between EMS and LSS and recognition of the benefits is unknown globally and by business sector.

- Research of current and future climate change legislation both in the UK and globally do not recognise the contribution that a tailored Environmental LSS approach could have towards assisting companies reduce their environmental impacts.

The outcomes of the literature survey provide a level of focus and direction for the research in the coming chapters. However in order to facilitate this progress it is necessary to understand and select the appropriate research methods. This will be conducted in the following chapter 3 by the researcher.

3 Research Methodology

Section Aims and Deliverables

- Evaluate and select suitable Research Methodologies that will enable the research to be conducted systematically and effectively
- Describe and visualize a concept ELSSSA Framework Roadmap based on the literature review and the researcher's own widespread experience of Lean Six Sigma Deployments
- Clarify the disadvantages and limitations of conventional LSS Audit processes and the need for change
- Identify the key requirements for the LSS Audit Software Platform
- Conduct a market survey of potentially suitable off the shelf software for the LSS Audit process
- Design and test a Pilot LSS Audit for a conventional and popular LSS tool
- Implement the Pilot Audit within a selected Industry sector and conduct analysis on the results
- Following feedback, clarify initial conclusions and next steps for the research

3.1 Introduction

The research methodology provides the strategies and techniques employed to facilitate answers to the research questions. In order for this to be effective it is important that the research questions, methodology and resources are all well matched (Manstead and Semin 1988). Consequently, this chapter begins by considering the research methodology that was selected.

3.1.1 Research Philosophy

In the Western tradition of science, two major research philosophies have been identified; these are namely positivism and interpretivist (Galliers 1991). Positivist methods are often considered to start with a theory from which a hypothesis is subsequently deduced and tested by the researcher, whilst with interpretivist the research is considered to result in a theory. An example of this is given by Spradley (1980) who stated that positivist researchers were akin to petroleum engineers whom with the aid of maps venture out to find something specific. Whereas interpretivist researchers can be compared with intrepid explorers who will venture out into the unknown and subsequently take readings from their compass which enables maps to be drawn up and developed.

Research within the fields of organisation research and information systems undertaken by Vreede (1995) observed that interpretive research until the late 1970's was the most common method employed however positivism has become the norm (Orlikowski and Baroudi 1991) and most widely accepted approach with over 96% of research using this theory.

3.1.2 Research Strategy

There are a wide range of research methodologies that exist that are available to the researcher. Galliers (1992) listed fourteen methods employed for the positivist and interpretivist philosophies as depicted in Table 3.1.

Positivist	Interpretivist
Laboratory Experiments	Subjective
Field Experiments	Reviews
Surveys	Action Research
Case Studies	Case Studies
Theorem Proof	Descriptive/Interpretive
Forecasting	Futures Issues
Simulation	Role/Game Playing

Table 3.1: Types of Research Methodology (Galliers 1992)

This thesis does not take the position that any method is inherently superior; instead the important thing is to match the research questions with most appropriate strategies. Moreover, as this research addressed multiple questions then rather than isolate a single method for the whole study; a sequential mixed methods approach was adopted (Creswell 2008) whereby the most appropriate method was identified at each stage of the research.

3.1.3 Research Methodology Selection

Following the completion of the literature survey and its conclusions it was deemed necessary to further understand LSS and Environmental management from the perspective of the LSS community. Furthermore, the intention was to gain understanding of the broad international picture to gain a balanced world view and understand the similarities and differences that exist. Consequently, a survey or questionnaire method was identified as most appropriate.

The rationale for this decision is that surveys enable the researcher to quickly and effectively obtain data through the use of questionnaires. This allows the researcher to study a much wider range of variables than is realistically possible via the use of laboratory or field experiments. Face to face interviews in comparison to surveys would take both considerable amounts of time to conduct and also garner potentially restrictive perspectives especially when a global understanding of LSS and Environmental Management perspectives are sought by the researcher. In addition it is easier and quicker to use the quantitative data obtained from a survey to clarify key relationships via the use of statistical methods.

The next Chapter 4 compares and discusses in detail the types of survey methods available, method selected and the development of the survey and issue to the Global LSS community. The subsequent Chapters 5 to 7 present the results from the survey and analyse and discuss these results statistically

The second type of research method selected was the case study. Case studies are defined by Yin (1994) as an "empirical enquiry within a real life context, particularly when the boundaries between phenomena and context are not clearly evident" and provide the researcher with a method to gather practical data and feedback for a relatively small sample size. Case studies callow the researcher in practice to act as a detached observer and the data gathered can be both quantitive and qualitative.

They are also useful when used as part of pilot studies (Yin 2003) in order to refine research plans and data collection methods.

Therefore the case study method will be particularly useful during the Proof of Concept (POC) pilot phase discussed in Section 3.4 where a suitable software platform will be selected, tested and evaluated in an industrial case scenario as part of the research methodology. In order to achieve this, a widely used LSS technique will be chosen and this will ultimately be developed into an Environmental version of a LSS Tool (Chapter 8). This will form the backbone of the ELSSSA tool that can be used as operational assessment method through various industry sector types. The testing of the ELSSSA tool will culminate in a 2nd case study. Strategically this will provide feedback that will demonstrate the success and lessons learnt of the research methodologies that have been employed.

3.2 Concept ELSSSA Framework

The concept framework devised by the researcher is based on over 15 years' experience of Lean Six Sigma deployments in numerous industry sectors and from the literature reviewed in Section 2. The aim is to develop this concept further through the development and analysis of a Global Lean Six Sigma survey, and the development and testing of a widely used Environmental Lean Six Sigma tool.

The initial concept ELSSSA framework (Figure 3.1) consists of 4 main phases, with each of these following a systematic sequence. Each of the phases is defined as the following:

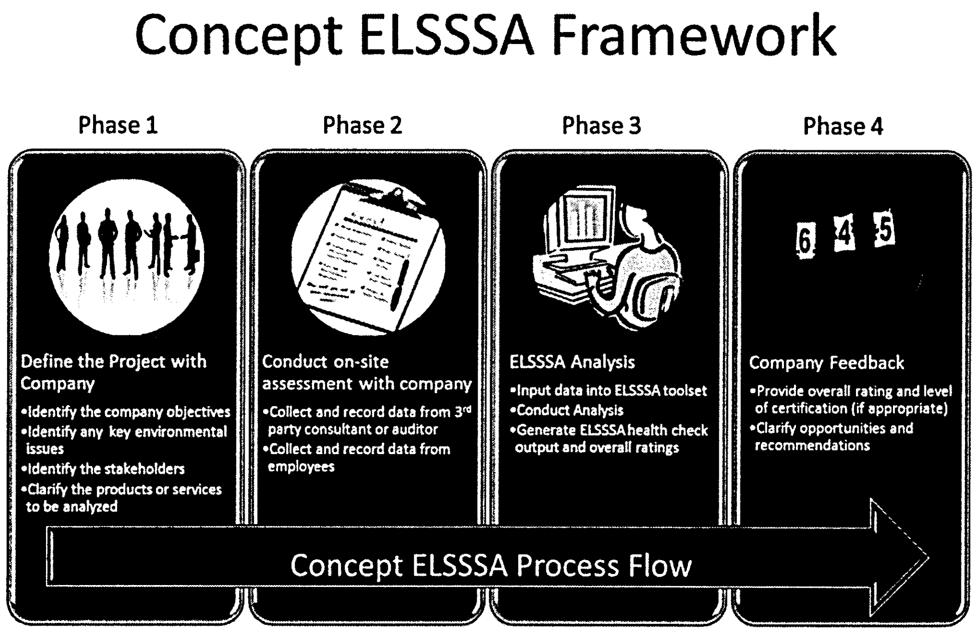


Figure 3.1: Concept ELSSSA Framework

3.2.1 Define the Project

The initial stage will involve identifying the short to long term objectives of the organization that is to be assessed. This phase will also identify any environmental impacts and issues within the organisations; these could be either existing issues or potential issues for the future of the business. In addition, it will clarify whether these are included or aligned to the company objectives.

At this stage the key stakeholders (Figure 3.2) will also be identified and mapped. These stakeholders could include Customers, employees, shareholders, suppliers and the local communities that may be impacted by the organisation.

Gaining their buy-in will be crucial to the long term sustainability of the project and its goals (Perrini and Tencati 2006). It is also highly important to involve all levels within the organisations from senior (CEO, Directors and Senior Managers) all the way through to the operational employees. Their lack of engagement will not present a balanced perspective of the organisation during the assessment phase (Weiss 2008).

The final part of this stage will be to identify the products and/or services to be assessed by the project team. It is important to use tools and techniques that will allow focus on the most critical products, services or processes in line with the organisations KPI's.

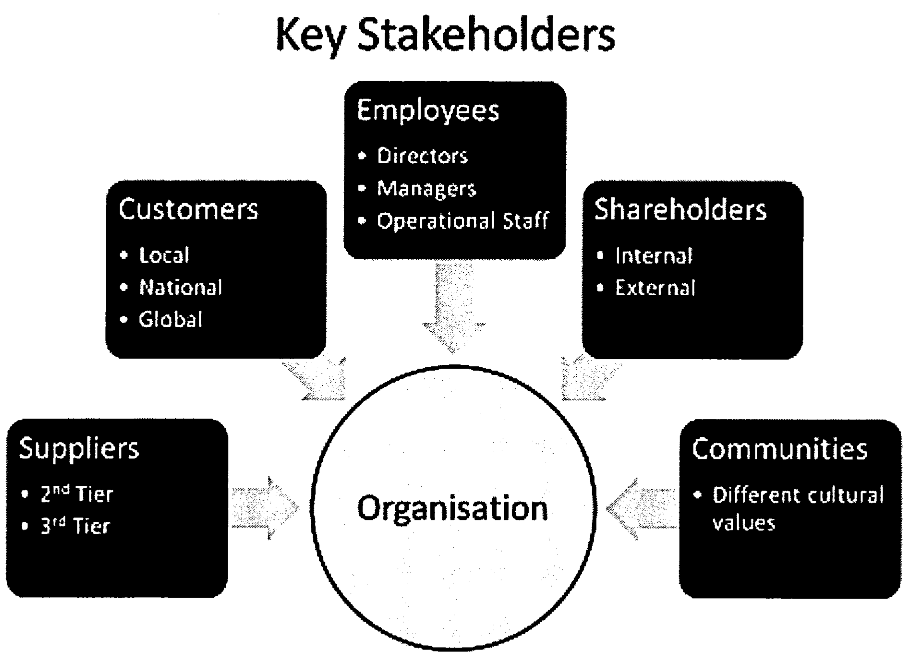


Figure 3.2: Key Organisation stakeholders

3.2.2 Conduct on-site assessment

The on-site assessment will be conducted by a trained internal auditor, trainer or external consultant. It is envisaged that audit data will be collected using a modified off the shelf software product either through email or using a web based process.

The audit data will be derived from a series of questions based upon specific commonly used Lean and/or Six Sigma tools and techniques such as 5S, 7 Wastes, SPC Control Charting, FMEA, and Poke Yoke etc.

The assessment will differ from conventional Lean and or Six Sigma assessment methods by focusing on the environmental impact of these tools and techniques rather than cost, quality and delivery benefits only. It is recognized there could be cases where there are QCD benefits but the environmental impact could be negative.

Each question will have a rating which will gauge the success of the implementation and the resulting benefits. The questions will also allow an anonymous forum for users to describe the positive and negative side of the implementation within their own function.

In addition to assessment of Key LSS tools and techniques there will be an environmental stakeholder audit. This will be aimed at the different stakeholder levels to gauge the buy-in to environmental improvement within the organisation and the key concerns both in the current and future state.

3.2.3 ELSSSA Analysis

The vision with the ELSSSA is to have the capability to analyse the data from the respondents using the modified off the shelf software product. The software will be used as an audit tool to gauge how successfully Lean Six Sigma tools and techniques have been implemented in the organization and how they are performing in relation to environmental impacts. Ultimately it is the aim of the research to develop specially tailored Environmental Lean Six Sigma tools and techniques and assess these. For example, these could be called Green 5S or Environmental 7 wastes.

As the audit data will be delivered to the assessor via email and/or a web based process, this will allow for remote analysis of the respondents data which will reduce costs and lead-times. The software will have the capability to produce reports such as graphs and tables automatically. Additionally, it will also measure the sustainability of the approach in terms of stakeholder commitment.

3.2.4 Company Feedback

The use of the audit software will allow for each function or department to have a score based on its own performance. In addition it will clarify where the specific strengths and weaknesses lay within their Lean Six Sigma and environmental management deployments.

The feedback will be provided by either the on-site auditor or external consultant depending on the situation that exists regarding deployment of the process. As well as this feedback, it is also envisaged that the analysis will help identify where the opportunities that reside for improvement lie within each specific department/function. Therefore where there are departments that excel in particular areas these can be identified and used for benchmarking purposes and these lessons learnt can be transferred to other departments or functions. This knowledge exchange is a key element of the ELSSSA process.

An Environmental LSS improvement plan would subsequently be developed clarifying specific improvement projects, stakeholders and responsibilities, timescales and project milestones.

3.3 Design and Testing of a Pilot Sustainability Assessment Process

3.3.1 Background Research

The need for a LSS Sustainability Audit methodology was borne from both the author's personal experience of ineffective Lean Six Sigma assessment processes over the previous fifteen years and research that examines the reasons for failure of Lean and Six Sigma approaches (Peterka 2007, Flinchbaugh 2006, and Carnell 2004). These popular theories include cultural readiness, management commitment, inadequate training/education and dilution of the core approaches amongst others.

What is clear is that each organisation is unique and there is not one single solution that can be prescribed to solve the problems of providing continuous sustainability. Therefore, it is useful to provide a method of assessment so that the issues preventing sustainability can be identified and worked on to improve the probability of success.

Within this part of the thesis the short term strategy is to therefore develop and optimise the proposed sustainability model for a selected LSS tool, to prove the audit process itself. In subsequent sections of the thesis this audit methodology will be developed into a new Environmental LSS tool and audit methodology (both covered in Section 8). The longer term aim will be to develop further environmental Lean Six Sigma tools and Audit methodologies and ultimately an operational environmental Lean Six Sigma sustainability assessment (ELSSSA) Framework.

It is envisaged that the sustainability audit methodology will help facilitate the success of Lean Six Sigma by providing companies with an insight as to what exactly is preventing the approach from being sustainable within their own workplace from an overall perspective through to individual departmental levels. These specific causes once clarified can then be acted upon using a suitable continuous improvement planning process with key stakeholders from the project.

3.3.2 LSS Audit Processes

Traditional audit processes have existed for Lean and/or Six Sigma (and the tools and techniques within these approaches) for more than 10-15 years. These are used to identify the success of the Lean and/or Six Sigma approach and to identify where opportunities lie to improve their deployment within specific areas of an organization. These audit processes in the main have been developed in a bespoke manner in-house by medium to large organisations or by consultancy companies who specialize in the deployment of LSS.

These audit processes analyse specific Lean and/or Six Sigma tools and techniques can provide a rating for each tool on a scale rating basis. These audits tend to be conducted either internally by trainers, process champions and/ or the process users. Alternatively the process is conducted by external parties such as management consultants or the end customer.

However these Lean and/or Six Sigma Audit processes are very limited in their deployment. The vast majority of organisations who implement Lean and/or Six Sigma yield projects focused on quality, cost and delivery improvements. They may also quantify these benefits but they don't tend to measure the effectiveness of the deployment of the key tools and techniques within their business. In addition, they don't analyse the stakeholder commitment to these approaches and individual tools and techniques.

The Lean and/or Six Sigma Audit methods that do exist are mainly prevalent within manufacturing in particular the Aerospace sector. These have been in existence since the late 1990s as a method of gauging the capability of the implementation of Lean internally with the different functions in the business albeit mainly within production. The assessment method also focuses on the senior management commitment to the principles and applications of process improvement but not on the other key stakeholder types.

Due to the success within the Aerospace sector these audit processes were subsequently deployed to their 2nd or 3rd tier suppliers under the term "Manufacturing Excellence", which is part of the Lean Aerospace Initiative (Murman 2002). Other similar schemes deployed in the Aerospace sector have included "Fit for the future" (Roe 2002) and (Grant 2003) which were popular at Marconi (now owned by BAE Systems) and Smiths industries (now owned by GE).

Many other Aerospace businesses and their suppliers developed their own frameworks which were similar in principle but under a different banner. As Lean and Six Sigma when deployed properly increases quality, decreases lead-time and cost a method of assessing their use within their supplier base (Achanga 2006) seemed to make perfect sense.

Ultimately through these assessment methods an audited organization is given a rating usually gold, silver, and bronze or ungraded if the score is below a certain level. These methods are still in use today; in the UK, a very popular process is an evolution of the "Manufacturing Excellence Programme" which is called SC21 (CAD CAM 2012). The SC stands for "supply chain" and the 21 for "21st century" and so far 120 Aerospace and Defense organisations have signed up to the programme.

More widespread in the UK and beyond are audit methods for individual Lean and/or Six Sigma tools and techniques rather than the whole approach. The most common is 5S auditing (Rahman et al 2010) (Gomez et al 2010), and these score each of the 5 Individual "S" which are added to provide an overall score. However 5S is only a one element of the Lean Six Sigma approach and does not examine the overall stakeholder commitment across the different hierarchical levels of a business and therefore this can impact the sustainability of the tool. Its focus is much more on operational employees and supervisor levels and this can be restricting its overall success. 5S audit methods are deployed in most business sectors types in relation to the larger more sophisticated Lean Six Sigma audit processes which are more prevalent in Manufacturing and Aerospace sectors.

Benefits of LSS Audit Processes

Companies that have a large supplier base where quality, cost and delivery are critical are able to use this type of process to help clarify and classify the different levels of capability of their supplier base. This helps an organization understand whether an internal and/or external supplier is capable of delivering their products in a controlled and capable manner and if they cannot, which particular areas the supplier needs to improve to become more capable to meet the expectations of the customer.

In practice companies that are not capable and do not have the commitment to improve may lose valuable contracts but those that do want to improve have an opportunity to do so. Following the audit they will understand where they need to improve in terms of Lean and/or Six Sigma but may need outside assistance to help improve their own processes either by external consultancy companies or from the customer themselves if they are willing to assist. This type of assistance is very common in the Aerospace sector but less so in other business sectors.

Another key benefit is the potential increase of process ownership. By understanding where an organization needs to improve this can provide stakeholders with the mandate to improve through regular self-assessment.

Disadvantages and Limitations of LSS Audit Processes

Having used these types of audit processes over a decade in various organisations and industry sectors, a number of limitations have been experienced and identified from their usage.

1 Time consumption

The task of performing the LSS audit varies from company to company depending on organisation size and complexity but it usually consists of performing the audit, recording the information, then the generation of the results and the delivery of these results. Traditionally this is usually performed using a combination of pen and paper, and some basic software applications usually Microsoft Word and Excel. For an organisation which is deploying LSS in a medium or large way, this task is extremely time consuming and can become its own little industry. This consumption is multiplied by the frequency of the audit process which some organisations may perform monthly or even weekly in some situations. Also the audit process is performed on-site therefore for audits performed by external assessors such as customers and consultants this can also add time to the process when taking into account availability and travel especially on international deployments. This adds significant cost to the overall LSS deployment and the benefits may be outweighed or significantly offset by the LSS audit process.

2 Ineffective metrics / Lack of statistical analysis

On completion of a LSS audit the scores of each of the individual LSS tools and techniques are usually totaled and a score or percentage out of a 100 or a rating (e.g. Gold, Silver, and Bronze etc.) is used as the metric to measure the performance of the LSS deployment within a company.

At a basic level this does provide an indication of the level that a company or department has reached but that it all. There is no statistical analysis of these results which can enable the user to clarify trends or correlations between important input factors that may be assessed and the output responses.

3 No automatic root cause analysis

Once the audit is complete, the scores for each area are summed. Many companies subsequently display the score in the area assessed and may discuss the score at management reviews and area meeting on the shop-floor. However, they rarely provide the user with clear information concerning why scores within a particular LSS tool or technique are low. This would require a full investigation using root-cause analysis tools such as FMEA (Stamatis 2003) within the given area and when the situation has a high number of problem areas this can substantially increase workloads and time required for auditors and associated employees.

4 No defect control

The data added to the LSS relies considerably on the auditor or LSS area user entering the right information in the paper report and/or spreadsheet. If questions are missed or incorrect numbers are typed these errors can be missed and impact the overall Audit score for an area. This could therefore imply that an audited area has performed better or worse than it actually has; which make the audit process and time spent performing in very non value added and wasteful. It may also de-motivate the workforce and bring distrust of the audit process itself.

5 Complexity

Many companies once they have collected their LSS Audit data choose to enter the information into a spreadsheet. For large companies that may have large number of departments and employees implementing the LSS approach and subsequently who are audited this can produce extremely complex spreadsheets. These spreadsheets can be hard to understand particularly if it is used by people other than the creator. This complexity can and does lead to errors and can be off putting and confusing to users who are entering data.

3.3.3 Pilot LSS Tool Selection

LSS consists of a wide array of tools and techniques but there are is a select number of key tools which are used more consistently for Auditing purposes than some of the more specialist techniques. The reasons for this vary but are mainly due to suitability to audit type processes and popularity within the LSS approach. The researcher has found that from personal experience the most commonly used audited tools and techniques identified are generally 5S, 7 Wastes and Value stream mapping. Within structured auditing approaches used by the LAI for example the aforementioned tools are those recognized by suppliers (Parry, Mills and Turner 2010) and are therefore more likely to be audited.

5S was selected as this is a very commonly audited LSS tool and technique and is one of the most popular tools used during the early phases of Lean and/or Sigma implementations. This statement is backed up by the results obtained from the Global Lean Six Sigma Survey (Figure 5.12) where 5S is identified as the most commonly used LSS technique globally. 5S is very useful for gathering the low hanging fruit and gaining momentum for success however for many organisations this success is short lived and is not sustained (Ballë and Rëgnier 2007).

The aim of this section of the thesis is not to identify why 5S fails in general terms but to develop the basis for an audit tool which can be used by companies who currently use 5S. The reason for this is that each 5S implementation is different and the causes for failure and lack of sustainability also vary.

Research conducted by Kovach, Cudney and Elrod (2011) indicated that 44% of 5S implementations fail within Manufacturing and Service sectors. The main causes for failure of the 5S technique include lack of commitment from leaders (88%), not mistake proofing the root causes (75%) and failing to address workforce issues (50%), however as stated previously every company is different and numerous variable will affect the outcome . Therefore it is deemed of value to be able to assess a company's implementation and clarify the individual causes for failure as well as opportunities for improvement.

3.3.4 Key Requirements for Audit Software

It was necessary at this stage to clarify the key requirements for the audit software which would be used to manage the audit process from start to finish. Taking into account the current limitations of the existing LSS audit process the following key customer requirements were identified:

1. Audit Questionnaire Functionality

The audit software must have the capability to of producing a wide range of different question types. These should include multiple choice questions, click down questions where the user can select the correct answer that is applicable to them and open ended questions so that the user can add free text. It would also be useful if the software has an in-built spell checking facility.

The software should also be able to recognize weighting scales so that they can be used to summarize audit scores.

2. Audit Questionnaire Data Collection and Distribution

Distribution of the audit should be able to be conducted either by the paper, web or email. This flexibility is required because of the different situations faced by companies from different sectors and countries development. However, it is preferred that the distribution where possible is either by the web or email as using paper increases the lead-time of the process and increases the chance of errors or loss of data. Also of high importance is that the data collection by the software is both quick and easy for the auditor or user.

3. Compatibility

It is preferential that the software has the capability to perform all of the functions required however in certain cases the data may be required to be used with other packages. Compatibility is desirable so that output data can be easily imported into specific software. This may occur where the software does not possess enough advanced statistics compatibility where other statistical packages may be required e.g. Minitab or SPSS. Also for presentation purposes software such as Microsoft PowerPoint, Excel or Word may be required in particular in the feedback phase when presenting to key stakeholders.

4. Ease of Use

In general terms the software should be quick and easy to setup by the user. The graphical user interface needs to be intuitive without the need for specialist training. The software should have an inbuilt "help" function so that the user can easily gain the knowledge and confidence to develop and distribute audits to respondents. Analysis elements such as graphs and charts also need to be logical and quick to generate, and basic statistical analysis features also need to be systematic and easy to find within sub menu options.

5. Statistical Analysis Features

It would be advantageous for the software to have the capability to analyse a range of data types. Features that are desirable include averages (mean, mode and median), measurements of the spread of data values (min, max, range, quartiles, standard deviation and variance) and the divergence of the data values against normal distributions.

6. Cost

It is envisaged that the costs for the software itself should be affordable for SME type businesses and for a single license to be enough for this type of organization, more for large LTD and PLC type organisations. Other important factors to be taken into account during the selection process will be additional module costs and support in terms of online or phone. The final consideration will be upgrade costs and the frequency of these.

7. Customer Support

Customer support from software providers varies greatly and consequently this will need to be analysed. This investigation will look at the overall structure in place, locality (nationally and globally), the level of support including 24 hour phone, email and on-site services.

8. Training

It is envisaged that the software can be self-trained by the user using the manuals and self-help menus. However, if additional training is required for more advance features it is advantageous if the software provide offers the facility to train either on-site or nationally.

9. Credibility

Commercially each software provider will be examined to check their duration in the marketplace, how widely known the company is and whether it has an established customer base. Customer feedback will also be examined where possible along with its financial status.

10. Mobility

A desirable but not essential characteristic is the ability to perform the audit within a portable compact device such as a PDA or Smart phone device using a specially developed application. This would significantly reduce the overall lead-time of collecting and inputting data when compared to traditional paper audits.

11. Flexibility

Many software packages are inflexible and cannot be tailored and developed to meet a customer's specific requirements. All organisations have their own unique characteristics and it would be beneficial for the software to be configurable so that it can be adapted to meet these specific requirements.

12. Future Proofing

Considerations need to be made of the software product in terms of whether it will develop in the longer term in line with other compatible software (e.g. Minitab, and Microsoft products such as Excel and PowerPoint). Therefore is the software product a one-off or are new versions in the pipeline with added features that may be beneficial to the audit tool.

13 Capability to Generate Tables and Graphs

The software should have the inbuilt capability to automatically produce a range of graphs and tables. The graphs and tables generated should be fully editable by the user and be produced with minimal effort. The ability to cross tabulate data to understand differences in demographics (e.g. age, gender and location) would be of value. It would also be advantageous if the software has the capability to filter results to gain further analysis of the data. Another useful feature would be the ability to include ratings and weights for the tables. Finally to export the tables and graphs to Microsoft packages (or their equivalents) and to convert to PDF format is also desirable.

3.3.5 Audit Software Selection Process

The audit software selection process involved researching the numerous types of questionnaire / survey / data analysis software that were available in the market. These types of software were selected because they could provide the various question types required for the audit the means to send and receive data. There are a high number of software packages that can perform this type of function; this was sifted down to 4 packages for the purposes of this selection process. In addition, Excel was included as many users traditionally use Excel as a way of sorting and scoring audits.

Added to this the selection decision was based on the software company's ability to provide the software for the evaluation phase in section 3.3.6 and the capabilities of the software, support and cost.

Below are the 5 Software applications chosen as a result of the selection process: -

1 Microsoft Excel 2010

2 Survey Monkey

3 SNAP 9 Professional

4 Survey Methods

5 Nvivo

3.3.6 Software Evaluation

Each software package was evaluated against each of the key selection criteria defined in section 3.3.4

Key Criteria Selection Matrix

Each of the key selection criteria was scored out of 10 (where 10 are the best) and the results were added to the key selection criteria matrix depicted in Figure 3.3. To summarize Snap Survey achieved the highest score by a clear margin (115 compared to 91 for Survey Methods which was 2nd highest) over the other packages for reasons discussed in Section 3.3.7. It scored consistently high across the majority of criteria selected particularly in important areas of data collection, questionnaire function and compatibility with other packages. In the event that the scores had been very similar further scoring would have been conducted with weighted factors to decide the most appropriate package.

	Application				
Selection Criteria	Excel	Survey Monkey	SNAP 9	Survey Methods	Nvivo
Questionnaire Function	0	6	8	9	6
Distribution of Questionnaire	0	8	7	9	4
Collection of data	2	8	9	9	4
Compatibility	5	5	8	8	5
Ease of use	2	9	7	8	3
Analysis	5	3	8	3	3
Charts and tables	5	4	8	4	4
Distribution of Analysis	3	2	8	5	3
Cost	10	9	5	8	5
Support	7	3	8	5	7
Training	1	1	8	2	8
Credibility	6	3	8	7	7
Mobility	9	2	8	3	5
Flexibility	7	3	8	7	4
Future proofing	5	2	7	4	7
Total	67	68	115	91	75

Figure 3.3: Software Evaluation Criteria Scores

3.3.7 Evaluation Conclusions

Excel

Even though Excel was not designed for auditing purposes it can conduct certain functions quickly and efficiently. It is the most widely used software package chosen in this study and also by far the most familiar to the typical user. In general it is used globally by most companies to input data into to provide statistical output, measures and tables/ graphs for reporting.

However the lowest score was attributed to Excel quite simply as it was not fit for purpose as an audit tool. Its main drawbacks were it inability to provide different question types and the distribution of the questionnaire once created to the respondents. Audits created would be complex and cumbersome particularly as the audit became bigger and is issued to an increasing number of departments and people. Also when users made errors it was not always obvious that an error had been made without thorough inspection of the spreadsheet.

Its main strengths are its low cost, its familiarity in terms of function and its ability to product graphs and provide statistical outputs however this can become complicated also as the distribution size increases.

Survey Monkey

Survey Monkey is the world's most popular survey provider with over 4 Million users. The company is based in the USA and customer support is via email. Rather than the usual software license survey monkey is hosted on the user's behalf and charged a monthly rate depending upon the features the user requires. The software provides a range of question types and graphs and tables.

There were many commendable aspects to Survey Monkey. Its main positive attributes were that it was quick and easy to learn how to use the application. There were a good range of different question types when developing an audit as well as handy templates. Data collection was relatively easy to conduct and there was a high degree of flexibility in terms of the variety of ways you could create your survey links including emails websites, Facebook, blogs and Twitter pages.

Survey monkey also provides the facility to create graphs and charts; however these were fairly limited in their presentation. The major limiting element though was no real statistical analysis available even at a basic level. Therefore another software package would be required to analyse the data e.g. Minitab or SPSS at a more advanced level or Excel at a more basic level.

SNAP 9 Professional

SNAP Survey is a long established (30 years) company with over 30,000 users of it survey software globally. It has 4 offices (3 in Europe, 1 in the UK) and they have extensive experience in a wide range of industry sectors. SNAP provided a fully functioning evaluation version of the software and were very helpful and friendly both on the phone and online. The software also includes the facility to perform statistical analysis of the result and had a wide range of tables and charts available. Other attractive properties of the software included the ability to publish questions via the web, email, paper or phone. Further checks identified a full network license available within SHU.

From the evaluation, Snap Survey was the only package deemed to meet the customer and technical requirements to the necessary levels to deliver a 5S Assessment process. The application had the ability to build audits quickly and easily, which many of the other packages could also deliver apart from Microsoft Excel. However when combined with its ability to produce a wide range of graphs and tables its uniqueness began to show. Coupled with detailed statistical features normally found in packages such as SPSS and Minitab, the software made a strong case for itself.

Snap Survey also allows the user to publish the audit to users via email and on websites. The time to conduct the audit using this process is also drastically reduced in particular within medium to larger organizations. Rather than filling in the audit with pen and paper and entering the data later on onto a spreadsheet, the audit can be completed in a variety of ways. For example it can be conducted using a personal digital assistant (PDA) and the audit if required can be submitted for analysis instantaneously. Alternatively it can be completed on paper, scanned and read automatically for analysis.

Survey Methods

Survey methods is a US company that provides a web based survey product. It is available in 3 different levels from basic to professional. The basic package is free of charge but has limited functionality whilst the advanced module is $39 a month but has added features including generation of tables and graphs and compatibility with other products such as Microsoft PowerPoint. The Professional version also provides phone and email support.

In the short to long term this software is good value when compared to some of the other off the shelf packages tested here. Building an audit and issuing to respondent was fairly intuitive and quick. Also of note was the software ability to collect the data and to disseminate this data back to the respondents in a variety of compatible formats.

Where it performed less well as an audit tool was its capabilities in terms of data analysis where it was lacking. This meant that another package such as SPSS or Minitab would have to be used in parallel at extra cost and effort. Another minus area was its tables and charts which were not particularly configurable. Other areas where the package could be improved were the mobility of the software and its support structure which resides in the USA. There was no training available in the UK and phone support would prove to be expensive.

NVIVO

NVIVO is a software product with over 400,000 users and is used in over 150 countries globally. It is specifically designed to help users analyse documents, surveys, picture, audio and video. Its abilities include the capability to identify subtle trends from information that may not be immediately apparent to the user. It is fully compatible with Microsoft packages such as Excel and Word and its data can be exported to specialist statistical software such as SPSS.

This software package has a number of strengths including its ability to analyse the widest range of data media types from this evaluation. It has the ability to analyse questionnaires and surveys and therefore audits which is what is required. However what it lacks is the ability to create the questionnaire's and distribute these in the first instance which is crucial to the development of the ELSSS framework, therefore you need another application to do this.

On the positive side it can also export data to statistical packages such as SPSS for more detailed analysis of the information generated.

3.3.8 5S Sustainability Audit (SA) Design

The development of the audit took into account the requirements of the research and also utilised personal experience of performing 5S audits in a variety of industry sectors. The audit itself consists of two different sets of questions these are lead questions and specific audit questions based on the use of 5S within a specific area within an organisation.

Lead Questions

The first set of questions is general leading questions and the information from these questions will aid in the analysis phase. These general questions clarify certain information about the individual conducting the audit itself. These questions are used as variables which can be cross referenced with the 5S audit questions using the software application and this will aid in the generation of conclusions and recommendations with regard to sustainability of the 5S process. These questions include the auditors, gender, and role, duration of 5S training, department and company level amongst others.

Audit/Observational Questions

The 2nd set of questions is structured around each of the 5S Phases. Each individual phase has its own set of five questions or observations. Each question can be rated over a defined range from a minimum of zero to a maximum of four. Zero being observed as "never" and a four is deemed as being "always". This type of ratings scale was developed by the US Psychologist Rensis Likert (1932) and is viewed as an acceptable method for measuring self-efficacy from respondents (Maurer and Pierce 1998) when conducting empirical research.

With a total of 25 questions for the five phases of the 5S approach and a maximum rating of four for each observation, a maximum score of 100 can be attained from the 5S sustainability audit assessment. The development of the individual 5S questions themselves was conducted from personal industrial experience of 5S implementation and benchmarking of other 5S approaches from other organisations.

A useful feature of the Snap survey software is its ability to create multi language questionnaires which allow the user to switch from one language to another. Therefore when for example an English only speaker has to email an audit to a Dutch client, the audit is published in Dutch. When the questionnaire is returned in Dutch the English speaker can switch over using a "tab" function within the software and conduct the analysis in English with no problems understanding the Dutch auditor's answers.

3.3.9 5S SA Proof of Concept Industry Testing

The 5S audit required some initial testing to identify any issues that may exist with the proof of concept (POC). Once the questionnaire is developed within the software application it needs to be published. There are a variety of ways the questionnaire can be issued with the most popular being an email HTML file or by hosting a link on a website.

For the POC testing the 5S Audit was issued to the two organisations from Sri Lanka and the Netherlands. For both these clients the most suitable method was to publish the questionnaire as an HTML file, the link to which was emailed.

Once published the user simply emails the audit link to all the auditors of the 5S process. This can include cell operators, managers, 5S trainers and external 3rd party assessors. The file once received is accessed by the auditor and they complete the audit when the time is appropriate for them. When the audit is complete they simply click on the submit button and the audit is returned to the creator of the 5S sustainability audit. All the returned audits should be left as unopened mail and to access the data the Snap Survey software imports the data directly from the mailbox. These files are now classed as opened files in the mailbox.

A process flow diagram developed by the author depicting this process is shown in Figure 3.4. This was created by taking into account the capabilities of the software and the feedback loops to the client.

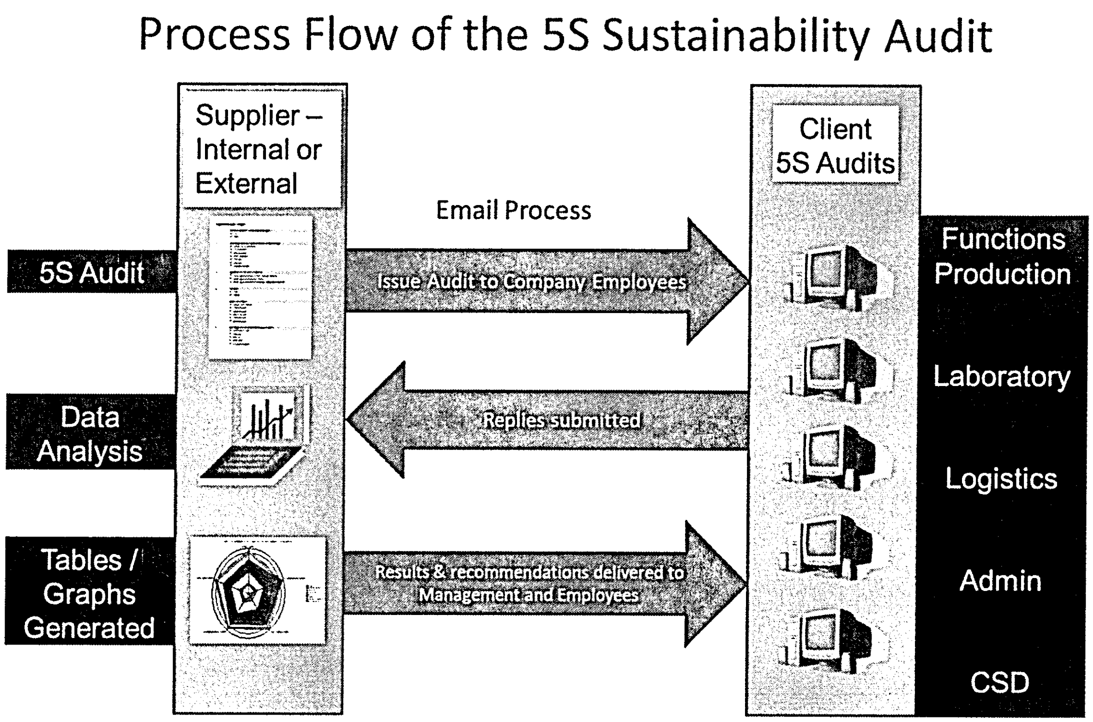


Figure 3.4: Process Flow of the 5S Sustainability Audit

Testing of the send and receive process of the 5S Audit proved relatively trouble free with no issues or problems. Completed example audits were collected for both the Dutch and Sri Lanka 5S audits and the next phase would be to develop the analysis process of the results.

3.3.10 5S SA Results and Analysis

In order to create the graphs and charts the software application had to have some logic applied. This consisted of creating a specific weighting factor for each value for each of the 5S audits questions. This was required in order for the software to understand that an observation rated as a 3 for example should be scored as a 3 within the application. Also for each of the 5S phases these had to be labeled via a "dummy" question or label in order for the graphs and tables to understand which questions were related to which phase of the 5S approach. These then needed to be applied to specific routing logic within the software.

With the necessary logic created, it was possible to create the tables and charts as required by the client. By combining the variables from the leading questions with the observations from the 5S audit it is possible to obtain some very interesting analysis and comparisons.

Taking the case data compiled from Sri Lanka textiles sector (sample size of 32 responses) it is possible to analyse the different between the leading questions and the 5S audit questions. Initial analysis of this data in Table 3.2 and Figure 3.5 shows a table and radar chart for comparing the leading question of department with the 5S audit responses. This shows clearly how each department is performing with regard to its 5S program for each individual phase. It can clearly be seen that administrations 5S programme is performing very well apart from the Sustain phase. Whilst in finance there seems to be issues across most of the 5S Phases, therefore highlighting a general issue with the 5S deployment within the area.

	Base	SORT Total	STRAIGHTEN Total	SWEEPING Total	STANDARDISE Total	SUSTAIN Total
Base	-	-	-	-	-	-
Missing						
No reply	-	7.33	9.67	12.00	8.33	1.00
Department / Function						
Production	-	11.38	12.63	13.13	9.63	7.00
Logistics	-	16.00	7.50	16.50	14.50	15.00
Administration	-	16.50	18.00	17.75	16.50	8.00
Finance	-	7.00	9.00	9.00	9.00	12.00
Laboratory / Testing / Inspection	-	17.00	16.00	14.00	15.00	5.00
R&D	-	8.50	9.25	14.75	9.25	7.75
Customer Service	-	15.50	15.00	18.50	17.00	7.50
Other	-	12.57	14.71	15.43	14.00	13.86

Table 3.2: 5S performance in relation to Function/Department

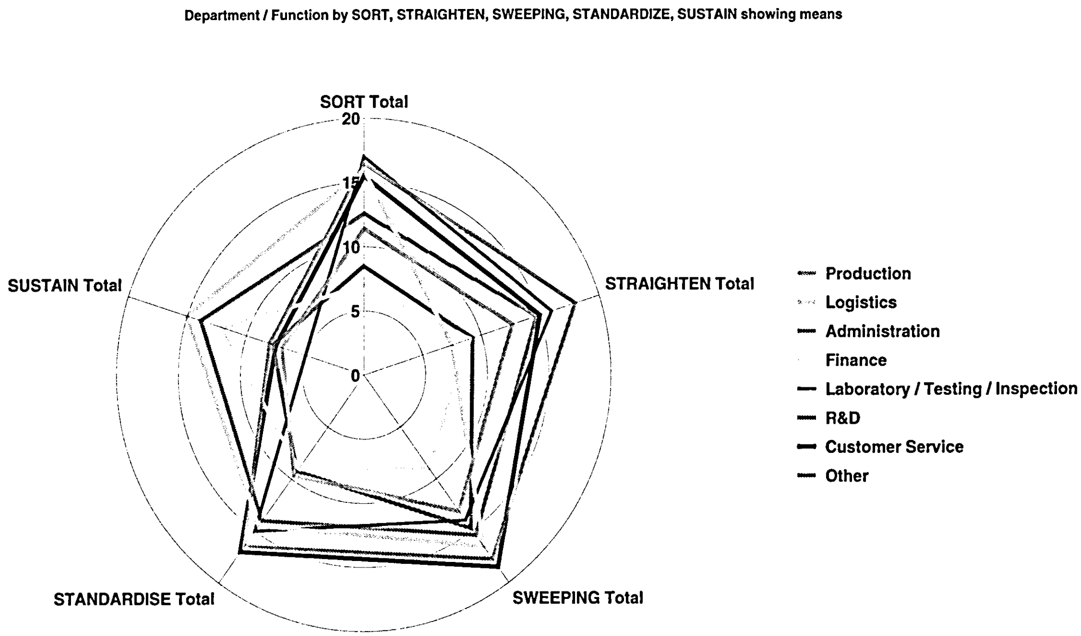


Figure 3.5: Radar Chart of 5S performance in relation to Function/Department

The reasons for the success and failure may not be apparent initially however by continuing the analysis using the other leading questions a picture can start to be developed of what is happening in each area. By adding variables such as "how long have you been trained" you could determine that the department has only recently being trained for example. Or it could be that certain employees have just joined the organisation and have little or no 5S awareness.

There could also be differences in opinions between different levels of the organisation demonstrating lack of management commitment or shop-floor fear of the 5S approach. This is where using the right leading questions with the general audit questions is crucial.

Initial analysis of statistical outputs from the 5S Audit showed how the tool can clarify valuable information to the user. The sample detailed in Table 3.3 contains statistics from Sustain Questions 15a to 15e. These clarify where more effort is required within that phase of the 5S approach within the topicality of team boards (mean 3) however the emergency equipment on the whole is highly visible (mean 4.516) and focus of effort is needed less here. The statistics also depict the variance of the results and where this is high, further investigation should be placed to determine why this is so within particular departments.

	Base	Missing	Descriptive Statistics							
		No reply	Count	Mean	Mode	Median	Minimum	Maximum	Standard Deviation	Variance
Have standard markings, labels, etc been used	32	0	32	3.3125	4	3.5	1	5	1.1022	1.214844
Is the team/cell activity board topical & up to date?	32	0	32	3	2	3	1	5	1.118034	1.25
Are all regular/moveable items 'footprinted'?	32	0	32	3.03125	4	3	1	5	1.334269	1.780273
Are all documents/ working instructions clearly identified?	32	0	32	3.4375	4	4	1	5	1.170937	1.371094
Is emergency equipment clearly marked & visible?	32	1	31	4.516129	5	5	1	5	0.79802	0.636837

Table 3.3: Table of Statistics from Sustain Questions 15a to 15e

3.3.11 Feedback and Conclusions on the Pilot 5S SA

Initial feedback from industry clients and fellow academics of the proposed 5S sustainability process has been positive thus far. Referring to the customer requirements for the process and the market needs defined earlier in the paper all of these have been met by the study. It has been important to meet these criteria for the model to be successful as part of the development process.

Managerial implications for this type of process are widespread as it can help make both strategic and operational decisions within the deployment of the 5S approach. It provides focus concerning where effort should be placed to get value added benefits and where effort should not be placed reducing waste.

The Snap Survey software has proved useful in its abilities to combine the questionnaire element with statistical capabilities to be able to produce tables and graphs which can be used to clarify opportunities for improvement in specific areas of the 5S steps. The ability to combine the output from the leading questions with the 5S audit question enables the user to "drill down" to get to the root cause or close to it. This will help reduce the time to get to the root cause and subsequently reduce the time to solve the problem.

The 5S Audit tool does have some limitations over conventional audits methods in existence, namely the initial cost of the software and the time required in getting acquainted with the various functions and complexities of the Snap survey. However when these are compared to the time it takes to collect and analyse data for conventional audit processes the payback is soon realised. When this is also coupled with the abilities of the software analysis capabilities the disadvantages become less important.

Now that a suitable software platform has been adapted and proven with a conventional Lean Six Sigma Tool, the next step will be to develop an environmental version. Before this can happen however we need to understand the key environmental drivers for organisations using Lean Six Sigma and what particular tools and approaches are appropriate to be adapted for use by these organisations. For this a Global Lean Six Sigma survey has been identified as they next key requirement as part of this research.

4 Global Lean Six Sigma Survey Development

Following the development and testing of the sustainability assessment for a conventional LSS tool there was a requirement to develop and undertake a global LSS survey in order to understand the LSS community, its views, needs and concerns in relation to the environment.

4.1 Introduction

The use of questionnaires to clarify the justification for research and development of new products, processes and services is well documented. A questionnaire was deemed as a necessary requirement at this part of the study to provide the focus and direction for the next phase of the research in order to determine the answers to the key points made above.

Questionnaires surveys can be conducted in many different ways these include but are not limited to:

1. Postal
2. Online and Email
3. Telephone
4. Face-to-face

4.1.1 Postal

Before the rise of email and the internet, postal surveys were the most popular methodology for many decades and were also usually the least costly to undertake. Postal surveys are in principle relatively straightforward in their development and deployment. However the cost effectiveness of postal surveys is highly reliant on upon the quantity delivered and the demographic of the survey recipient. For example with global surveys they can become expensive due to postal costs which can become excessive and also their cost effectiveness is also dependent upon their response rates from the recipients. B2B International (2012) has identified that the variable costs for 1000 surveys to be around £600-£800 with the biggest costs being the printing of the survey and the postage.

Research has shown that typical response rates for a postal survey are in the region of around 25% (Greer, Chuchinprakarn, and Seshadri, 1999 and Cobanoglu, Warde and Moreo, 2000) but this can vary considerably between 5% to 50% (B2B International, 2012) due to a high number of input variables. These variables include number of survey pages, number of questions, survey content and the type of sponsoring organisation of the research to name but a few.

Low percentage returns can be increased by aiming the survey at the right stakeholders and types of organisations, but this can take time, knowledge and money. Also many respondents will not want to pay for return postage and therefore the researcher or their organisation may need to pay for postage costs.

Other ways of increasing the response rates are by providing incentives these could include discounts for products, and/or services or by sending out reminders. The two most commonly cited reasons (Baruch 1999) for the poor response to postal surveys are that the correct stakeholder did not receive the survey and the second is that the respondent simply did not want to complete it. The latter can be broken down to the respondent not having the time, the survey not being relevant, surveys not being company policy to complete and that a return address was not provided by the sender. Another significant problem with postal surveys is that some questions may not have been completed by respondents which can result in data that is difficult to statistically analyse and achieve concrete conclusions.

4.1.2 Online and Email

Since the introduction to the masses of the internet, web based and email questionnaires are increasingly accessible (Kwak 2002) to the majority of the global population and across all age groups, levels of hierarchy and classes. The use of email asynchronous surveys began in 1986 (Kiesler and Sproull 1986) and web based surveys were first conducted in 1994 (Kehoe and Pitkow, 1996). They provide a quick and easy way to collect and analyse data (Andrews, Nonnecke, and Preece, 2003) that can be conducted at a lower cost than the other methods reviewed in this section.

There are numerous software applications and web based systems that can be used to develop and issue the survey. The results can be reviewed "live" as they are returned to the developer with minimal lag. The survey developer can develop the survey for free on a number of these systems and in a variety of formats and many of these applications offer the function of built in tables and charts which can greatly reduce the time to analyse and feedback conclusions.

With web based surveys care must be undertaken by the survey developer to ensure the consultation is on a topic of particular interest to the respondent otherwise the numbers completing on-line surveys will tend to be minimal. However, some groups of respondent may be less easily contactable by other survey methods (postal or face to face), so an online survey may be the best method for securing a sufficient response. Also unless the survey developer has large numbers of e-mail addresses within their network on line questionnaires are can be poor for sampling purposes, however they may still yield information of value whilst achieving this at low cost and risk.

A potentially significant problem with web based survey are that they are more vulnerable to being skewed by certain individuals with personal agendas or by specific interest groups and this is a possible reason for deciding against this survey type. This needs special consideration and the survey returns need to be checked for any potential bias. A well designed survey will increase the probability of flushing out any potential suspect survey returns. This problem however can be highly dependent on the subject matter in question, its ethical context and the reasons for the research.

4.1.3 Telephone Interviews

The use of telephone interviews either though cold calling or pre-arranged methods have been popular for many decades. The positive aspects of this method are that they make it possible to achieve high response rates and it allows questions to be asked speedily whilst under close supervision.

Research conducted by Brambilla and McKinly (1986) highlighted that responses for telephone interviews can be higher for white collar in comparison to blue collar workers, from people with higher rates of income and longer education. These points may need to be considered carefully when analysing respondent returns and the associated sample sizes for different user types, otherwise bias may seep in.

A potential benefit of telephone interviews are that compared to postal surveys they can also minimise non response to questions and also clarify reasons for refusal. This information can be useful for the survey and provide lessons learnt which would not be known from a postal survey. When they are planned properly telephone interviews can provide a cost effective means of sampling a large population especially for local populations, less so for global populations.

Where these surveys can fail are through minimal planning and cold calling which results in a high percentage of non-value added attempted calls that leave respondents exasperated and interviewers in a general state of despondence and lack of data. It can also be difficult to reach certain stakeholders at a convenient time for the respondent or even obtain their contact information.

With this type of questionnaire if the interview wishes to record the interview for analysis purposes he/she must inform the respondent at the start of the interviewing process.

4.1.4 Face to face

The final style of questionnaire reviewed here is more personal in its approach than the other types discussed. It can be conducted at the recipients home, at a pre-arranged destination or in a public places. However careful consideration has to be placed on where these surveys are conducted in relation to the purpose of the survey and target audience. For example where the local general public are sought to be interviewed, face to face can be useful when attempted in public places however for the purposes of interviewing people who are from a focused global discipline such as LSS users researched here, this may not be as effective.

Face-to-face interviews do have some benefits thought over other interview types. They can allow for allow more complex issues to be explored and also allows the interviewer to see body language responses (Job 1987) and ask follow on questions if something of interest or relevance is discussed. The interviewer can also use visual aids during the interview which may help with the responses generated.

Another benefit with this type of survey is if any recording is performed this can be easily reviewed and discussed with others. However this should only be done with the permission of the interviewee who must be notified at the beginning of the interview.

4.1.5 Conclusion

For the purposes of this research it was decided that both email and web based surveys would be most beneficial in terms of getting a global response and achieving a high sample size at minimal cost. Both these methods would be much quicker and easier to find the Lean Six Sigma user target audience via Lean Six Sigma websites and networks, which are covered in more detail in section 4.3.2. These two methods are also more convenient for the potential respondents who can complete the survey in their own time. The use of specialist survey software applications such as SNAP Survey also allows the respondent to complete the survey in stages if they wish which provides increased levels of flexibility.

The use of email through the author's global network of LSS users would create a "push" response and in parallel the use of a web based survey on a variety of LSS websites would help facilitate a "pull" response for LSS users who are openly willing to respond to the survey.

It was also deemed appropriate to use the SNAP Survey software to develop and issue the survey as it has the capability to sort and analyse the results. The author also felt confident from previous usage and assessment of survey packages to use this application.

4.2 Target Lean Six Sigma Users

Since its inception Lean Six Sigma is a growing approach globally, most successfully deployed in the USA, Europe and in the certain parts of Asia most notably Japan and increasingly China and India. The survey will target all the major continents so that key similarities and differences can be identified and analysed. Historically business process improvement approaches do change over time (Hoerl 2004) and by targeting the global LSS community this may provide insights into the emerging changes in terms of Lean Six Sigma and its ever growing community.

Over the last decade Lean Six Sigma has also been implemented in most types of business (Kwak 2006) from small organisations to LTD companies and large PLC organisations such as Boeing, IBM and GE and these different sized businesses will also be aimed at for this part of the study in order to gain a balanced perspective of the companies using LSS.

There are numerous types of users of Lean and/or Sigma in existence and these operate in just about every industry sector imaginable from Government to Healthcare to Electronics. These user types vary from general practitioners who implement Lean within their workplace on a full time basis to process sponsors\champions who offer senior stakeholder support on a part time or ad hoc basis.

Then within the Six Sigma and Lean Six Sigma discipline there are varying levels of "belts" (Henderson 1994) awarded depending on the level of capability and experience. These include Master Black belts that train, mentor and coach other lower order belts. Then there are Black Belts who deliver major projects and provide coaching and Green Belts who deliver projects at a more intermediate level. Finally, Yellow belts that offer support at review meetings and are generally are not involved in the detailed analysis and problem solving of the Lean Six Sigma approach.

4.3 Sample Size Identification

From exhaustive research through numerous academic resources and media types clarifying the population size of the Lean Six Sigma community globally is not an easy task and would appear to be unknown. Therefore it was deemed to be easier initially to clarify what the absolute minimum size of this global population could be use this to help identify the appropriate sample size for the survey. The actual population size would be larger of course however if the minimum population size is in excess of 20,000 it will not make any difference to the sample size. The calculation below shows that if the population exceeds 20,000 then the sample size should be in the region of 384 (Cochran, 1977) and this size would not need to increase any further even if the population was 1,000,000.

4.3.1 Sample Size Calculation

There are several factors that need to be considered before an appropriate sample size can be defined.

Cochran defined the following calculation for sample sizes for large populations: -

$$N_0 = \frac{(t)^2(p)\,(q)}{d^2}$$

$$N_0 = \frac{(1.96)^2(0.5)\,(0.5)}{(0.05)^2} = 384$$

Margin of Error (d)^2

The margin of error or confidence interval is defined as the amount of error that you can tolerate as part of a study. Typically 5% is the most commonly used value for categorical data whilst 3% is common for continuous data (Kotrlik, 2001). For the purposes of this research as we will be analysing categorical data, 5% margin of error will be used.

Confidence Level $(t)^2$

The confidence level is the amount of uncertainty you can tolerate within the study. The higher confidence level, the larger the sample size required. Typically choices for confidence levels are 90, 95 and 99%, for the purposes of this study we will use 95% which is the typical default for most academic studies. Higher levels of confidence level are usually required in studies involving safety critical processes, products or services such as aircraft components or food products.

In relation to the calculation defined by Cochran (1977) for categorical data, t^2 is the value Alpha level of 0.025 in each tail = 1.96.

Population Size (p) (q)

In relation to the calculation defined by Cochran (1977) p is the estimated proportion of an attribute that is present in the population, and q is 1-p. As clarified earlier sample sizes do not change much for populations over 20,000. This is depicted in the Table 4.1 assuming typical margin of error of 5% and a confidence level of 95%.

Population Size	Minimum Sample Size
100	80
200	132
500	217
1000	278
2000	322
5000	357
10000	370
20000	377
50000	381
100000	383

Table 4.1: Appropriate Sample Size Identification

4.3.2 Online Lean Six Sigma Population Sample Size Identification

From the calculation described previously if it can be proven that if the global LSS population size exceeds 20,000 users then if we have a sample size in excess of 384 it should be representative and we should 95% statistical confidence in the response.

The Lean and/or Six Sigma community has numerous on-line forums the most popular with the largest subscriptions included the Lean Enterprise institute, ASQ (American Society for Quality), ELSMAR, ISIXSIGMA, Quality Gurus and Kepnor Treqgu. Each site states its member numbers therefore it can be confidently stated that the forum site with the largest membership for Lean and/or Six Sigma must have the minimum population size for the Lean Six Sigma community in terms of forums.

The Elsmar cove forum has a total user base of over 128,000 members however this site covers other disciplines as well as LSS including quality management and ISO Standards, therefore it cannot be assumed that the 128,000 members are all LSS users. Within the specific forums for Lean and Six Sigma the number of different users is not identified however it does disclose the most viewed discussion items. The most viewed Lean discussion was over 28,000 and Six Sigma was over 34,000. Obviously a discussion item could be viewed more than once by a member but this is an indicator of the minimum LSS population size.

The ASQ site yielded less information as it disclosed the number of replies to a discussion item but not the number of views of an item. Therefore this avenue was not pursued any further. ASQ site members also cover more than just the LSS community. The Lean Enterprise institute forum website also did not disclose member numbers however its most popular viewed discussion was over 15,000 views and these were specifically on lean and not six sigma.

Quality gurus is an on-line free course provider and has over 13,000 registered users and focuses on quality management, Lean and Six Sigma. TreQna is an open source six sigma on-line forum and has a membership in excess of 10,000. Its main focus is six sigma and also quality management. It's most viewed discussion in excess of 11,000 views. ISixSigma did not disclose member numbers however it has the largest number of postings over 30,000 and had been established over 10 years.

It was difficult to conclude from the different LSS forum sites what the minimum population of the LSS could be due to many different factors. Some LSS could be members of more than one site for example, as indeed is the author.

Further research identified the professional business networking site LINKEDIN (www.linkedin.com) as a possible way for identifying the minimum population size of the LSS community. The networking site has numerous Lean and/or Six Sigma groups which are used for discussions, networking and LSS awareness and education. There were a large number of these LSS groups as can be seen in Table 4.2. These groups increased significantly since March 2010 where there were just 300 LSS groups a figure which has since doubled.

Group Type	Total Groups March 2012
Lean	1999
Six Sigma	968
Lean Six Sigma	630

Table 4.2: LINKEDIN LSS Groups

Of the LSS groups assessed it was found that the Lean Six Sigma group had the largest membership of over 108,000 users worldwide (an increase from 40,000 in March 2010). This group is aimed at users of LSS and this is a good predictor of the minimum LSS user community size.

Indeed keyword searching LSS within LINKEDIN within individual members yields over 189,000 LSS users in March 2012 (125,000 members in March 2010) who post LSS experience on their profile. However for populations in excess of 20,000 the sample size will not change significantly.

Using the assumption of a minimum population size of 108,000 the sample size is calculated as 383 which demonstrates little change from the 384 unlimited population sizes. This figure was double verified using sample size calculator on the web (http://www.raosoft.com/samplesize.html) and yielded the same 383 population size.

Therefore it can be concluded from this research that the sample size for the Global LSS survey should exceed 383 to provide the author with the required level of confidence in the data from the respondents.

4.4 Questionnaire Design

In order to achieve the desired response levels defined the design of the survey needed to be carefully considered. Research undertaken by Erdos (1970) identified that following factors needed careful consideration during the design phase of the questionnaire.

- Layout and structure
- Types of questions
- The length of the questionnaire and response times needed
- Colour of the Survey Page and text.

The initial draft outline for the questionnaire was designed and developed using the same software used for developing the concept Sustainability audit. Snap Professional Version 9 was deemed to have the necessary capability to provide the ability to develop and issue and return questionnaires whilst also being able to provide detailed analysis of the resulting data all within a single software package.

4.4.1 Layout and Structure

The start of the survey is designed to provide the recipient with the basis of the study. It outlines the name of the questionnaire and that it is anonymous and that the recipients would only be contacted if they leave their contact email address for a later stage of the research. It outlines the time range that the questionnaire typically covers and the contact details of the author if they have any questions or problems with the survey. In addition it outlines that the survey has been designed to be completed by those who have knowledge and experience of Lean and/or Six Sigma approaches.

The overall layout of the survey has been split into four sections these are as follows: -

A. Background information

B. Organisation Profile

C. General Lean Six Sigma Questions

D. Environmental Questions

These sections are clearly depicted within the survey and it has been constructed with separate pages for each section. In addition a progress bar was also incorporated which informs the user how much of the survey has been completed. This will in theory provide the user with the knowledge that the survey is accomplishing something and that it won't be too long before the end. Using SNAP Survey V9 the respondent can also complete the survey in stages if they are busy in their working environment.

Section A

This has been designed to gather basic information about users including their gender, age, time working for their current company and their organisation level. This information will be useful in cross referencing differences in relation to these factors during the structured analysis of the results.

Section B

It is intended to collect information about the user's organisation such as global location and the type of business structure that they belong to. This section of the survey also clarifies the main business sector that the organisation is a part of and the department or function that the user works within. As in section A this information will be cross referenced in the Results and Analysis Section 5 and 6 to identify similarities and differences in response from different industry sectors, global locations and function types

Section C

Section C will gather details of the survey recipient's experience of Lean Six Sigma including training, roles, tools and techniques used and the types of benefits achieved through its deployment in their businesses. It will also clarify the duration from using these business improvement approaches and what their biggest concerns are of their own deployments in their own organisation.

Section D

The final section explores what the users think about LSS in terms of environmental benefits and trade- offs from its deployment. It also clarifies their awareness of new environmental versions of LSS and the different types. In addition it asks their opinions on the benefits of combining LSS with Environmental Management processes and their thoughts about environmental legislation. This section of the survey also gauges their own personal concerns about the environment and clarifies the driving forces within their organisation towards becoming green. The survey asks the recipients of what LSS tools and techniques they consider to be of value if developed from an environmental perspective which links to the research objective discussed earlier. This information will be of value when developing the ELSSS Framework as it will help clarify which tools are potentially of value if developed for the global LSS community who are key stakeholders to any future approaches and tools\techniques.

The survey ends by asking the recipients if they are interested in the research to leave their email contact details. Those who have left these details could at a later date be contacted and further information that could be valuable to the research may then be obtained. The survey ends with the earlier contact details of the author if there are any questions or problems with the questionnaire. At the bottom of the page there is a submit button which will automatically deliver the survey to the author.

4.4.2 Types of Questions

Snap version 9 employs a wide range of question types at its disposal. All the questions within Sections A and B is drop down questions where the recipient simply clicks on the option that is relevant to them. This speeds up the questionnaire process for the user and makes the analysis of the data within the software quicker and more error free.

Within Sections C and D the survey mixes different type of questions. These include one answer and multiple response, multiple choice type questions. This part of the survey also uses open ended questions where opinions or personal experiences are sought by the author and for where the answers aren't readily known or confirmed within the LSS community. The final question type used is grid first which is a single answer question provided in a multiple choice format and will ensure that the respondent considers the most important factors from a personal perspective with an element of prioritization.

4.4.3 Length of Questionnaire and Response Times

Careful consideration was placed on the length of the questionnaire, too short would clearly result in failing to achieve the objectives of the study and too long would potentially mean a reduced number of responses. This assumption is backed up by research (Greer, Chuchinprakarn and Seshadri 2000) that identified a likelihood of response of 69.23% for a 2 page survey and 30.14% for a 4 page survey. Other research undertaken by Hoinville, Jowell and Airey (1978) suggests a survey should be within 6-8 pages of A4. In contrast, Jobber (1989) found that through his research found no significant statistical difference between the responses for a 5 or 9 page questionnaire issued for an industrial mail survey.

Taking into account the potential trade-off between survey length and responses it was deemed that the on-line survey would be designed to have eight screen pages of questions for the user to complete. Realistically it was felt the user could realistically complete the survey within 10 minutes but this would be confirmed through the pilot test process. This estimated completion time would be clarified on the first page to make the survey seem less daunting to the respondent.

4.4.4 Colour of Survey Page and Printed Text

Many research studies have been undertaken analysing the colour of survey pages and its ability to increase responses (Jobber and Sanderson 1983). One of the clear advantages of on-line surveys in relation to postal surveys is that a web survey can be delivered in colour without the need for printing and there is no additional cost. Printing in colour is expensive and many organisations may not have the facility to do so without outsourcing it to another company which can also increase the overall lead time of survey development and delivery.

Due to the environmental context of the research it was deemed that the use of green colouring would be appropriate for the purposes of the survey format.

4.5 Questionnaire Testing

It was necessary to conduct some internal testing of the questionnaire before issue to the LSS community to ensure that no defects occurred later during the delivery and subsequent receiving of the output data. Any errors during these phases of the study could result in either poor response percentages or response answers. The outcome of this could potentially manifest itself in the form of having to repeat the survey again which would delay the research considerably therefore the testing programme was critical at this phase.

4.5.1 Questionnaire Structure, Format and Grammar

The survey was subject to a number of checks to ensure no errors were present. The SNAP Survey software has a feature which allows the user to publish the survey as a preview only. This provides the user with the survey in the exact form that the recipient will see on delivery. This gave the opportunity to adjust the structure of each of the questionnaire pages so that they filled the page in a proportional manner. The preview also showed that some of the text required adjustment in size and position on screen and the built in spell checker highlighted any spelling defects and these were corrected accordingly.

On completion of this initial check by the author, the questionnaire was checked again by two colleagues to highlight any further changes that may be necessary to the survey and the proposed changes discussed and acted upon where necessary.

4.5.2 Internal Survey Previewer Pilot Testing

The next phase of the pilot testing, involved publishing the newly modified questionnaire and then personally completing it on screen. Once submitted this creates a 'previewer' version of the questionnaire which is delivered to the authors email inbox. This process was completed a total of ten times and subsequently the inbox checked to determine if all ten submissions were successful.

Once Snap 9 professional is open, the submissions can then be imported with the data entry page. The data was subsequently checked for any errors that may have occurred. The software proved very robust with no mistakes reported or found by the author at this stage.

4.5.3 External Pilot Testing

The final phase of the testing involves publishing the latest version of the survey in a web HTML format. This creates a HTML file and a number of jpeg image files which need to be hosted on a webpage. Once hosted the web address of the file needs to be sent to the recipients. At this stage of the testing the web-link was distributed to several pre-selected colleagues who then were tasked with completing the survey in a normal manner answering the questions as they would any other survey. Snap Survey has a function which will identify how long each recipient took to complete the survey. The average time it took to complete the survey was 6.5 minutes (4-13 minutes) so the guide on the front page of 5-10 minutes was kept in the survey.

The results from the survey were subsequently checked section by section for errors and defects but none were found, during this validation. The final validated version of the survey following the testing phase of the study can be found in Appendix A.

4.6 Distribution of Questionnaire

Following satisfactory completion of the design and testing phase it was now necessary to issue the survey to the global LSS community in an unbiased manner in a way that could not influence the data returned. To minimise bias the questionnaire was issued onto various global Lean and/or Six Sigma forums and group sites, these have been listed below:-

- iSixSigma Forum
- Elsmar Forum
- Benchmark Six Sigma Forum
- Lean Enterprise Institute Forum
- ASQ Forum
- TreQna User Forum
- LinkedIn Business Networking Site

The intent with the questionnaire was to collect a minimum of 383 responses from the global LLS community.

The following message was posted online at the various Lean and/or Six Sigma forums and group sites listed above and includes the link to the online web questionnaire: -

---

Dear Fellow Lean and/or Six Sigma Users

I'm currently researching a PhD exploring Lean Six Sigma and its environmental benefits and/or trade-offs. For my thesis I'm analysing the key differences between different industry sectors and departmental functions.

Could you help me out, I have created a survey for users of Lean and/or Six Sigma. It takes 5-10 minutes to complete and it is completely anonymous. Please pass to colleagues, contacts or friends who are Lean and/ or Six Sigma users where possible.

Your help is greatly appreciated, please follow the link below: -

http://www.greenleansolutions.com/shu/LSS/survey

Kind Regards

James Marsh

Senior Researcher

Sheffield Hallam University

5 Global LSS Survey Results

This section of the report has the following objectives:

- Identify the Global LSS community key characteristics including basic user information, demographic usage and industry sector types.
- Clarify the status of the new environmental LSS approaches including the different variants in existence.
- Determine which specific LSS tools and techniques should be developed into environmental versions and subsequent assessment methodologies.
- Identify the environmental benefits and disadvantages experienced by the LSS community from using LSS approaches.
- Identify the general concerns of the LSS community towards the environment and the combined use of EMS practices with LSS.

5.1 Introduction

On completion of the questionnaire testing and its issue onto the various Global Lean and/or Six Sigma forums and networking groups, the next stage of the research process was to receive the responses from the Global Lean Six Sigma community.

The responses automatically entered the researcher's email inbox and these must be kept as unread until they have been uploaded onto the Snap Professional software. The respondent's data was subsequently imported into Snap Professional on a daily basis and backups made in case of any problems.

The response to the questionnaire was overwhelming with a total of 451 responses which was more than the 383 than was aimed for based on the assumptions of the minimum global population. From this sample 64 LSS users send personal emails asking about the research and wanting more information. The survey was anonymous but 143 LSS also left their contact details including email addresses wishing to receive further information on the research.

5.1.1 Exporting the Snap Survey Data

For ease of use and compatibility the results were exported into Excel and analysed statistically where required using Minitab V16. To export the data the survey the Case Data button needs to be selected in Snap Survey and from here the File Export needs to be chosen from the main toolbar. From the Data Export window the Comma Separated Format (CSV) is selected.

There are a number of export options which need to be considered when exporting the data into Excel. The options for header row, label row and code labels need to be chosen and as there are a number of multiple choice questions in the survey the Expand Multiples box also needs to be chosen. This allows any multiple choose question response to be expanded into individual columns once in Excel and this will save time when sorting through the data and conducting analysis.

Once this was exported it was possible to open Excel and view the data in the format required.

5.1.2 Presentation of Results

The presentation of the Global LSS survey is based upon the basic structure of the questionnaire which covers the four areas below: -

1. Background Information
2. Organisation Profile Questions
3. General Lean Six Sigma Questions
4. Environmental Questions

In addition for selected questions the results have been filtered to highlight key differences or similarities in responses for example by company location and also by industry sector. This will facilitate additional discussion points for the analysis of the results and help contrast any key research outcomes from the survey responses. Any filtered questions will be labelled in the bottom right hand corner showing what the data has been the filtered by, it will also label the sample size that has been used. Any figure without a label in this area will contain the full sample size of 451 responses.

5.1.3 Respondents Background Responses

Figure 5.1 to Figure 5.4 relate to basic information about the respondent covering their gender and relative age. It also captures length of service at their current organisation and the level that they are currently at within their company.

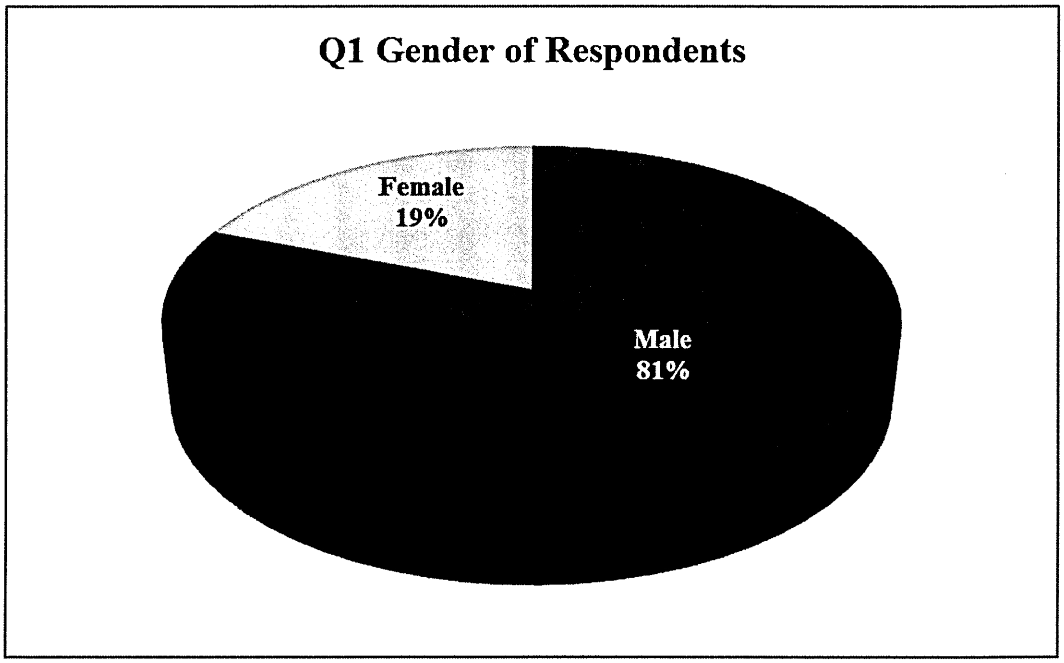


Figure 5.1: Respondent Gender

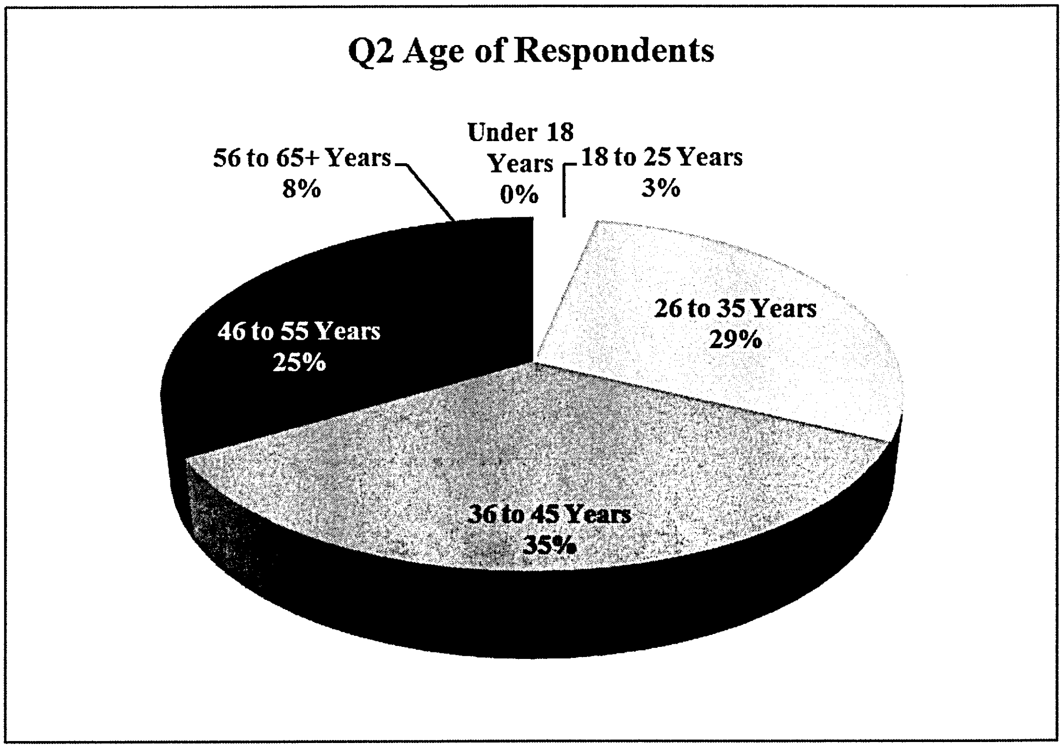


Figure 5.2: Respondent Age in Years

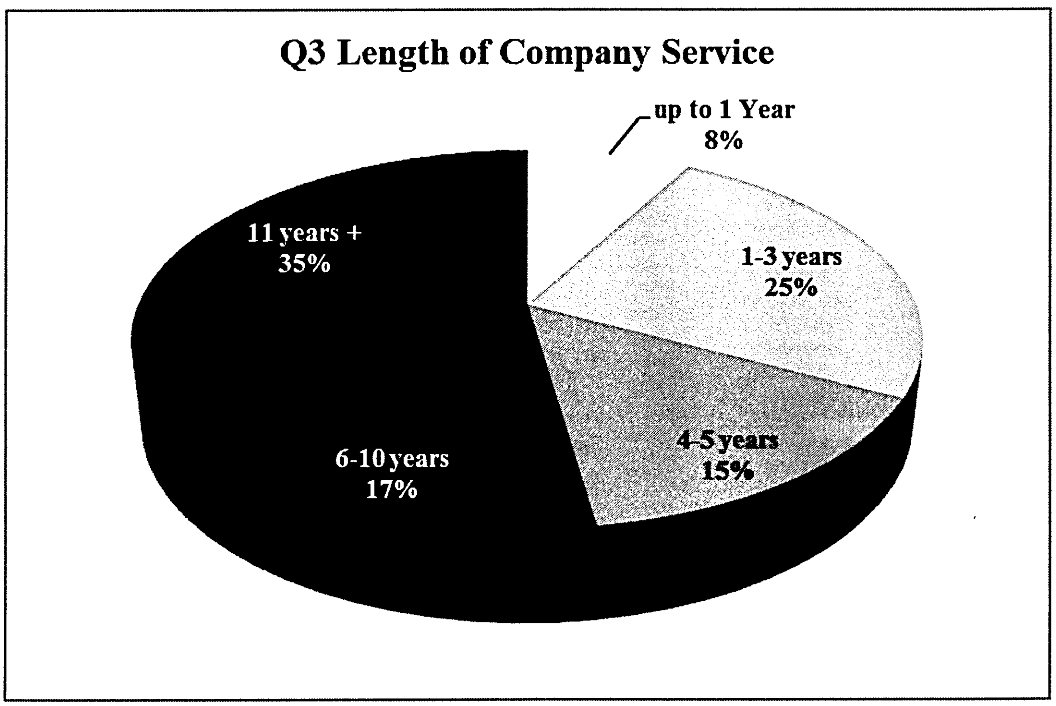


Figure 5.3: Respondent Length of Company Service

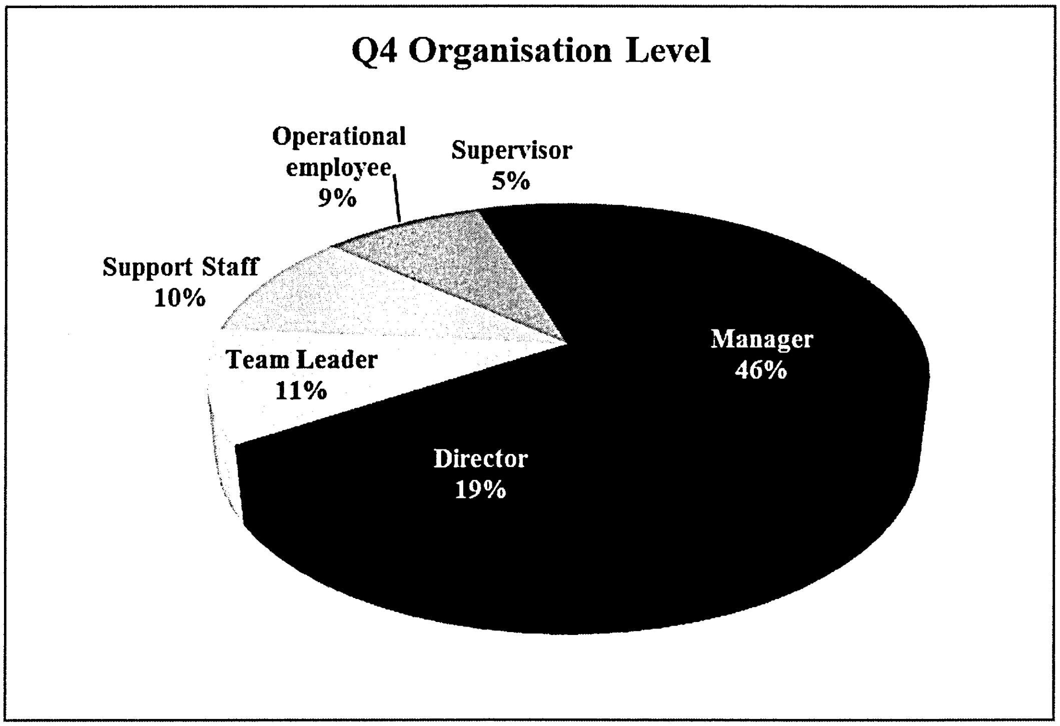


Figure 5.4: Respondent Organisation Level

5.1.4 Organisation Profile Responses

The results in Figure 5.5 to Figure 5.8 correspond to the information regarding the respondent's organisation. The figures provide information on the general location of the company and the type of business structure that the organisation belongs to.

In addition the results show the specific business sector types that the respondents company is involved in and the actual job function that the respondent works in.

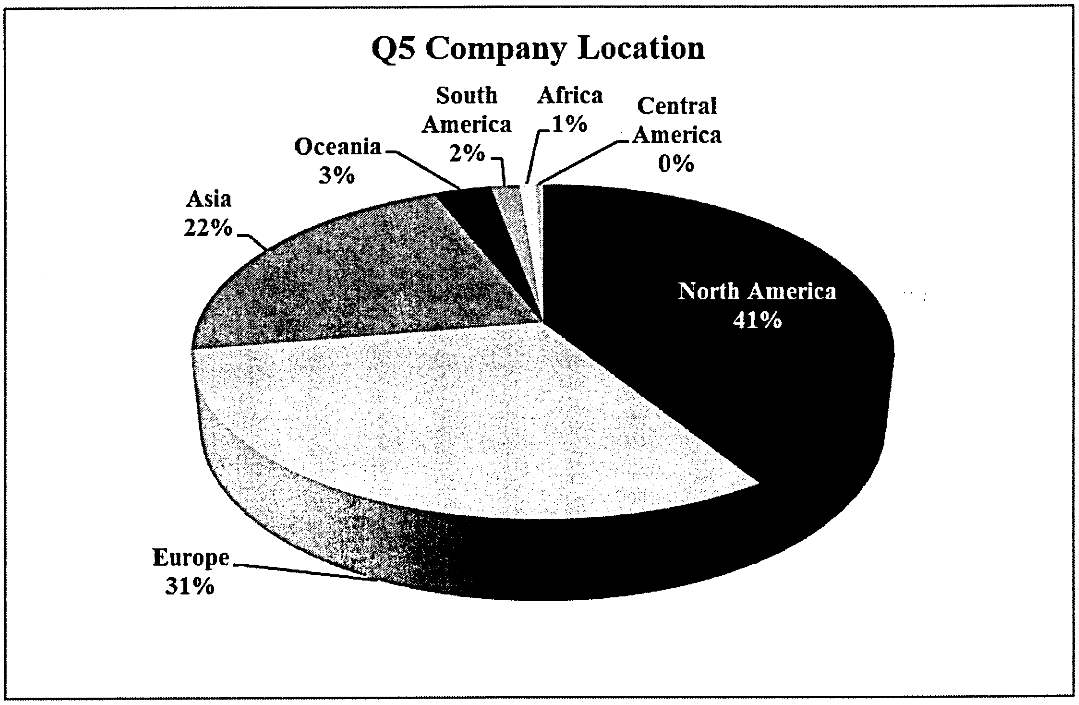


Figure 5.5: Respondent Company Location

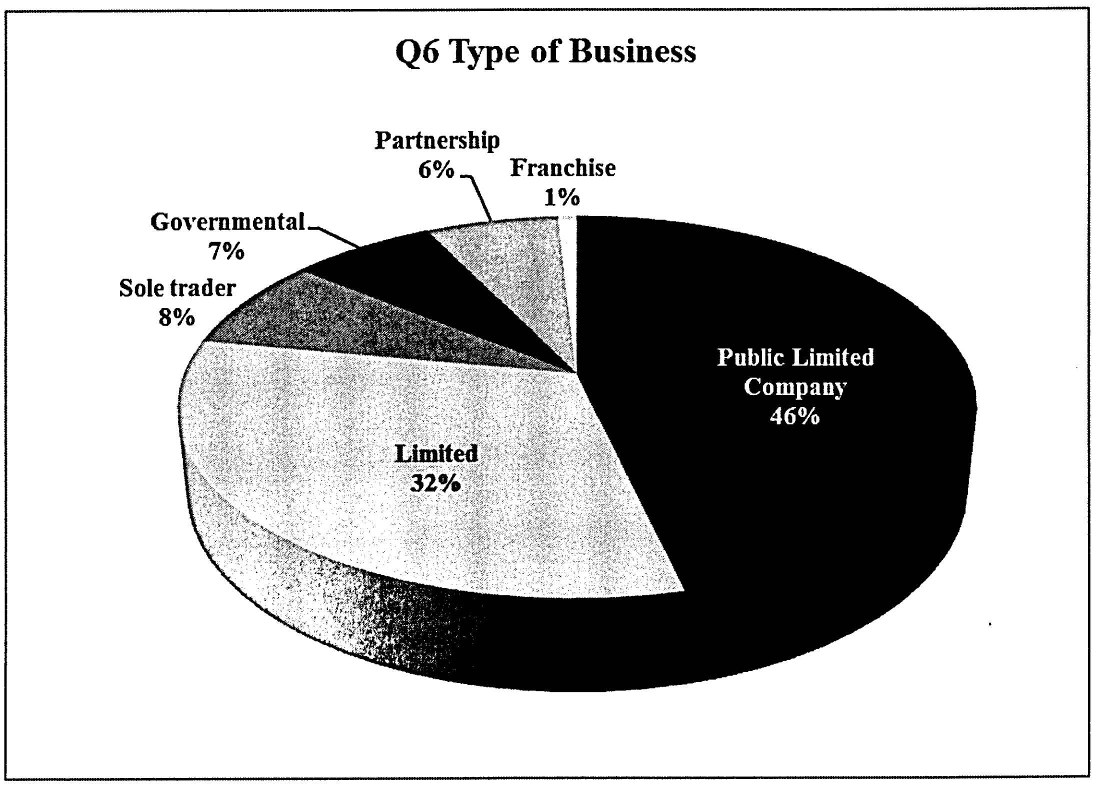


Figure 5.6: Respondent Business Structure Type

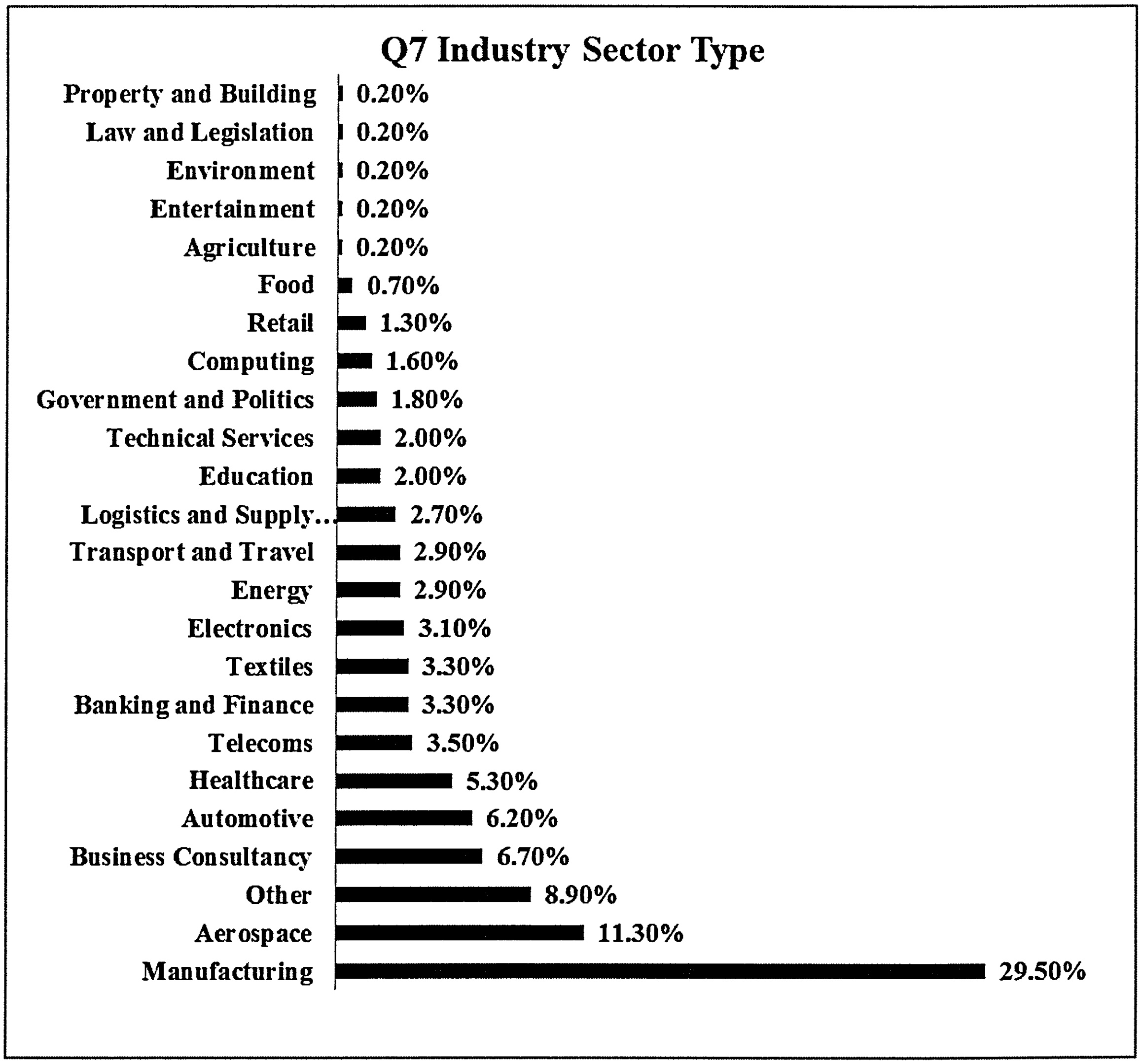


Figure 5.7: Respondent Industry Sector Type

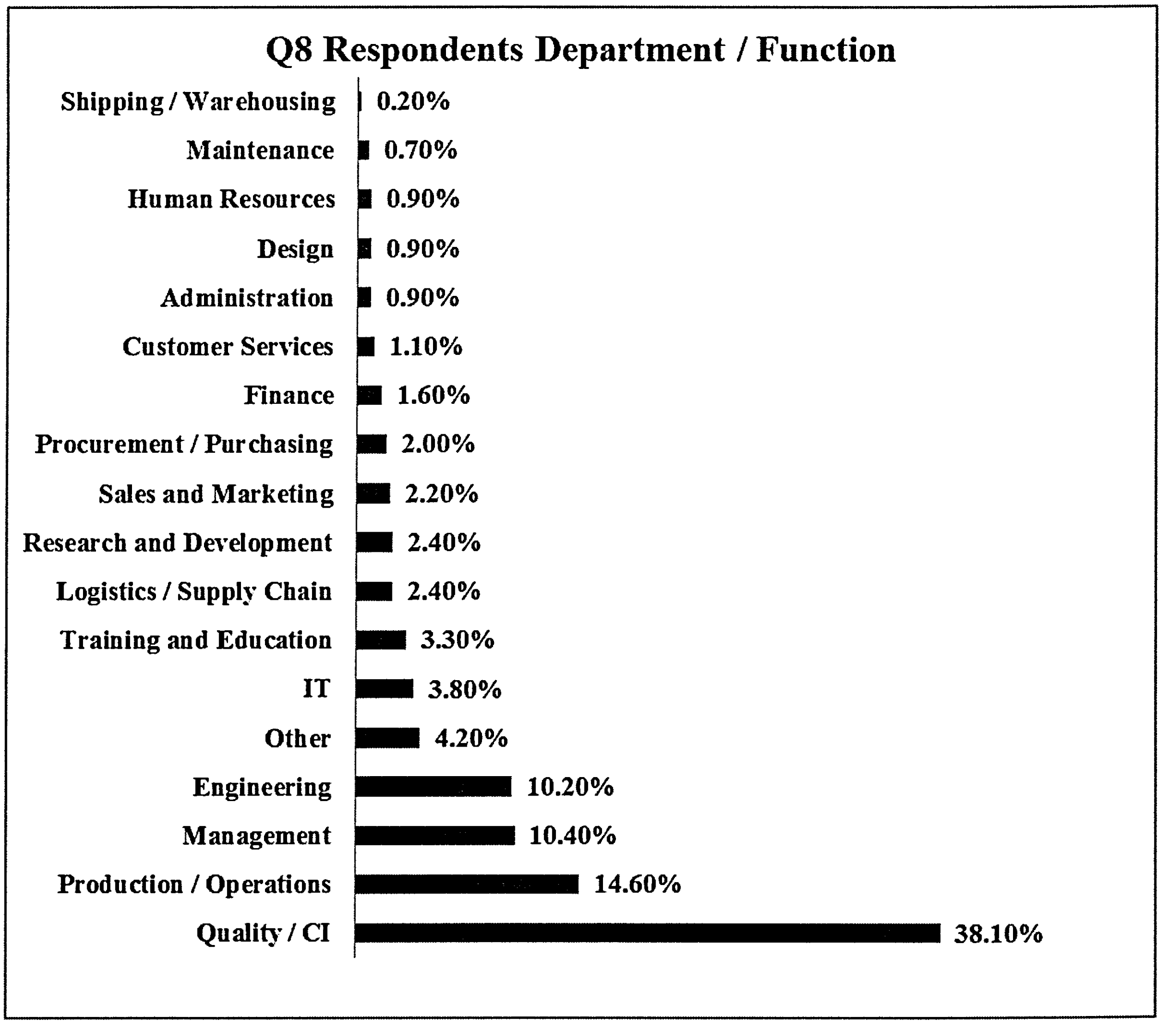


Figure 5.8: Respondents Function or Department

5.1.5 General Lean Six Sigma Responses

Figure 5.9 to Figure 5.17 establish information of the respondent experience of LSS. Initially, the report presents the respondents training in the area and duration of using the approaches. In addition the actual role that they possess in terms of LSS deployment within their organisation is identified along with the specific LSS tools and techniques that they use in their organisation.

The types of business benefits that they have experienced through the deployment of LSS are quantified and the level of success that they consider that has been achieved is also presented. Finally the biggest concerns that they have over their LSS deployments in the business are presented.

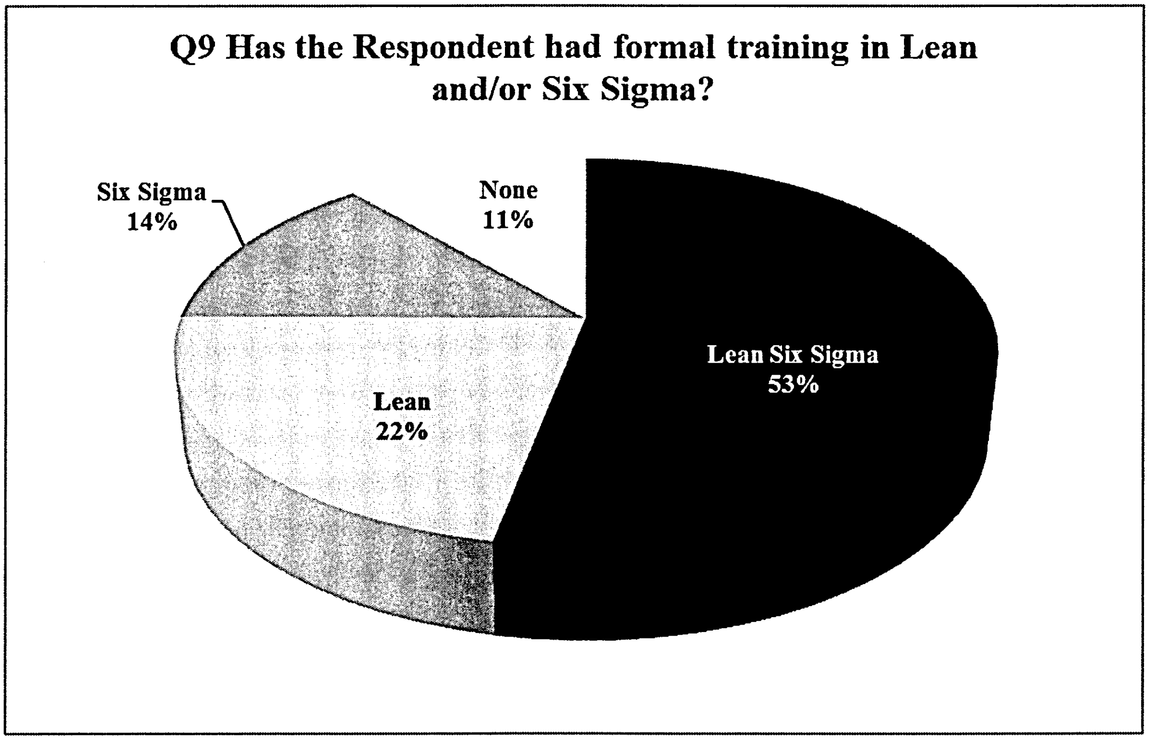


Figure 5.9: Respondent Lean and/or Six Sigma Training

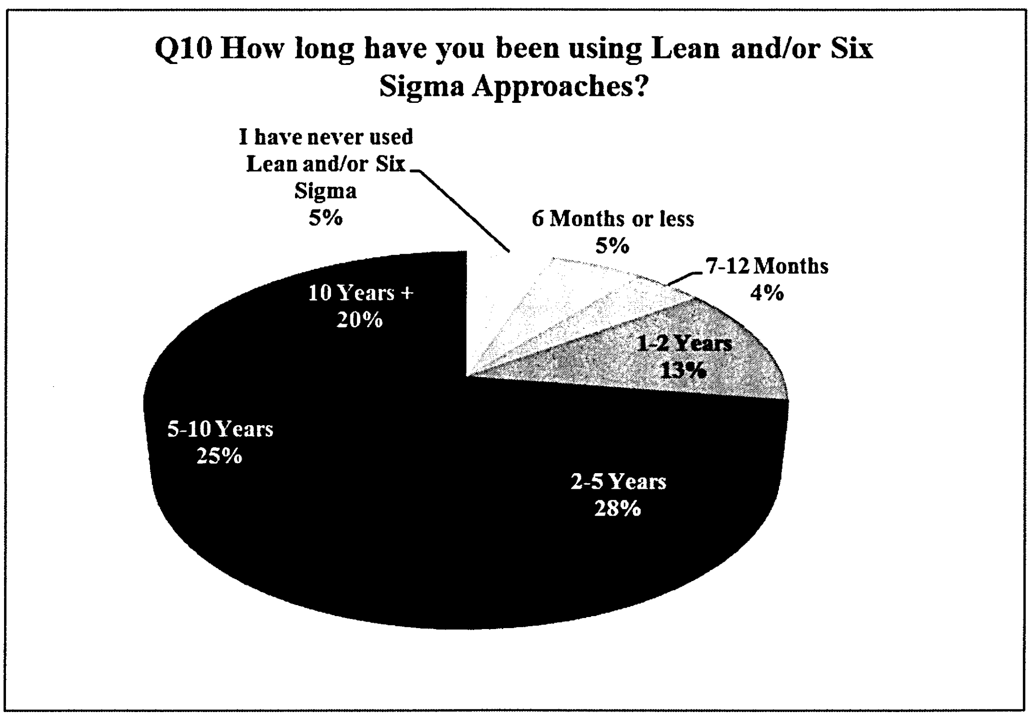


Figure 5.10: Duration of using Lean and/or Six Sigma Approaches

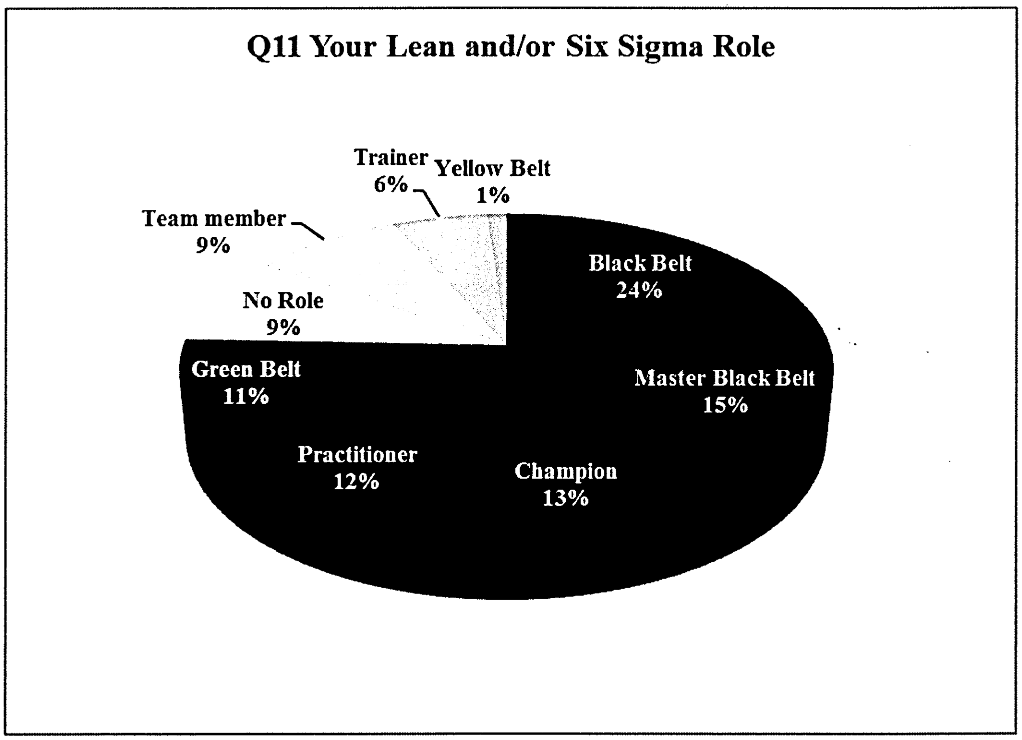


Figure 5.11: Respondent Lean and/or Six Sigma Role

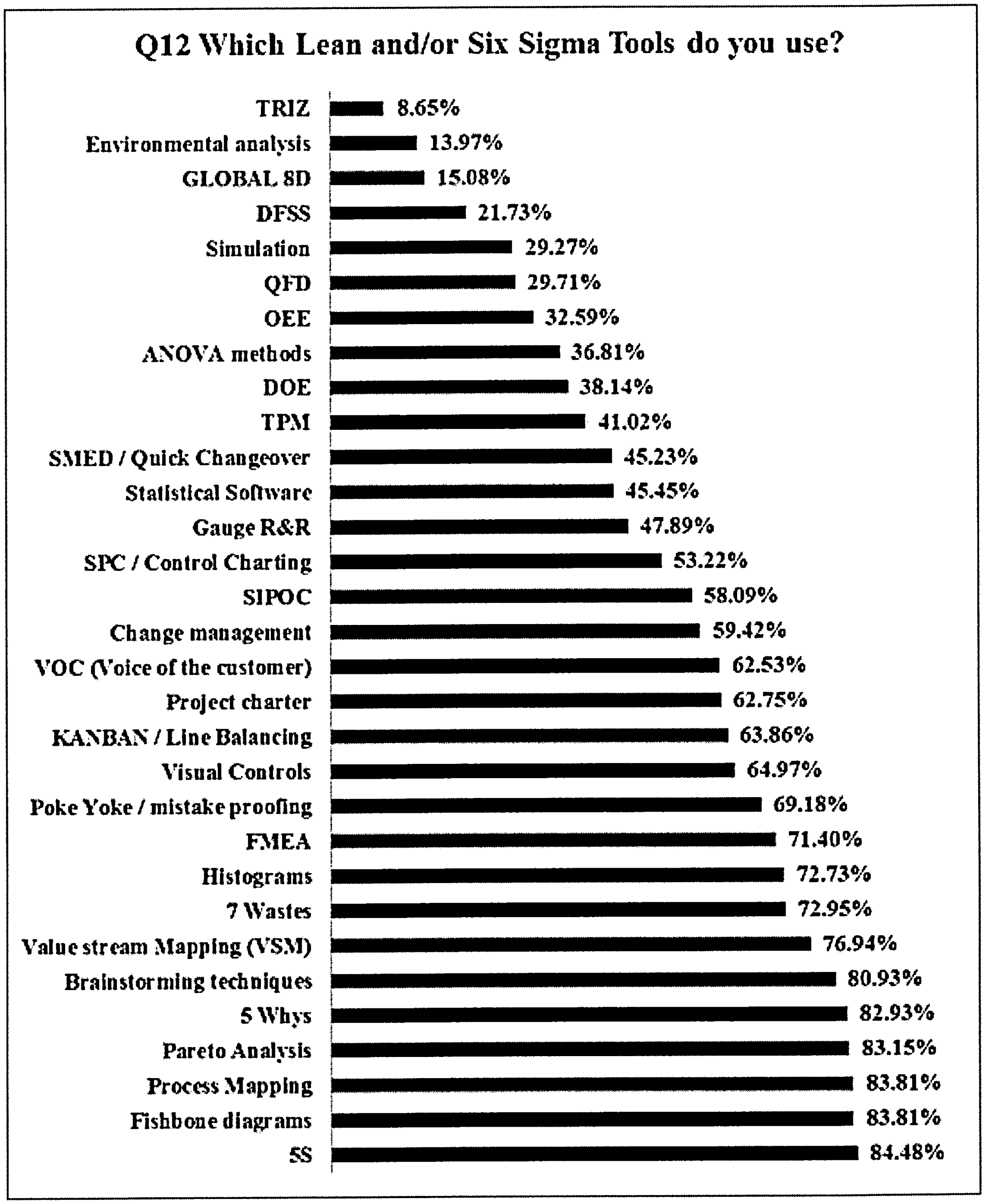


Figure 5.12: **Respondent Lean and/or Six Sigma Tools used**

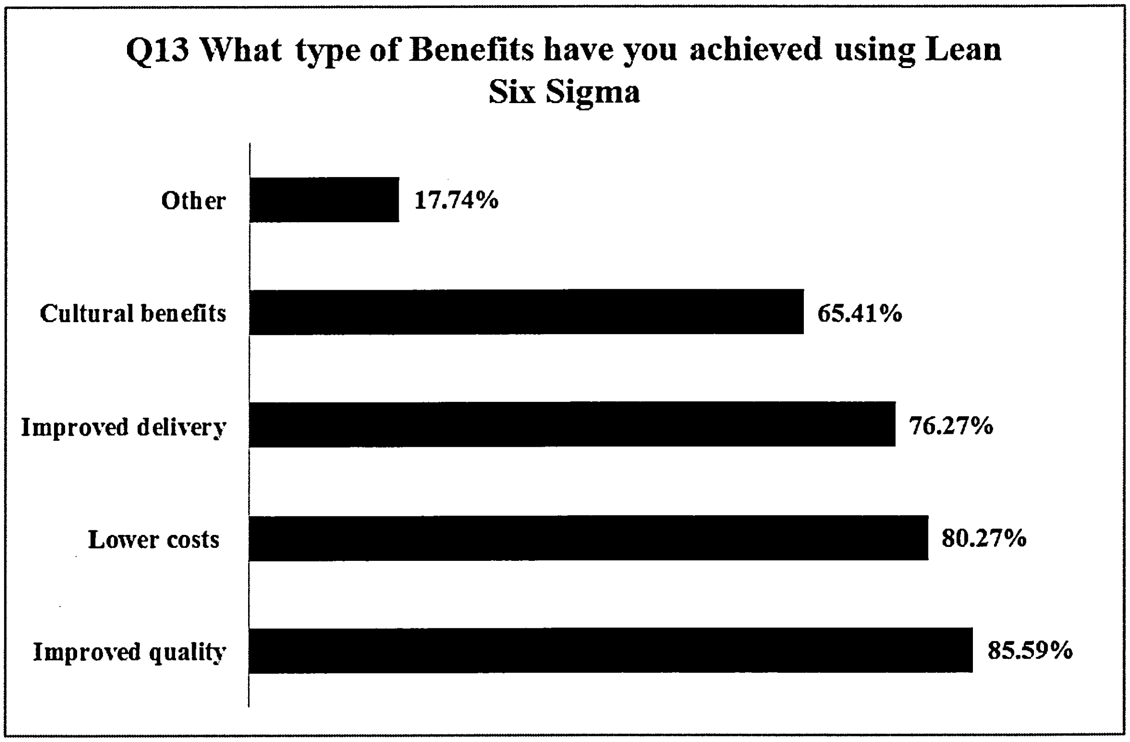


Figure 5.13: Respondent Benefits from using Lean Six Sigma

Data from question 14 was optional for the respondent to add their own specific benefits if not listed in the options available in question 13. These responses were manually taken from the Excel Spreadsheet and categorised. The large percentage of these responses was repeated answers (8.87%) and the remaining were low in comparison to the others listed in question 13.

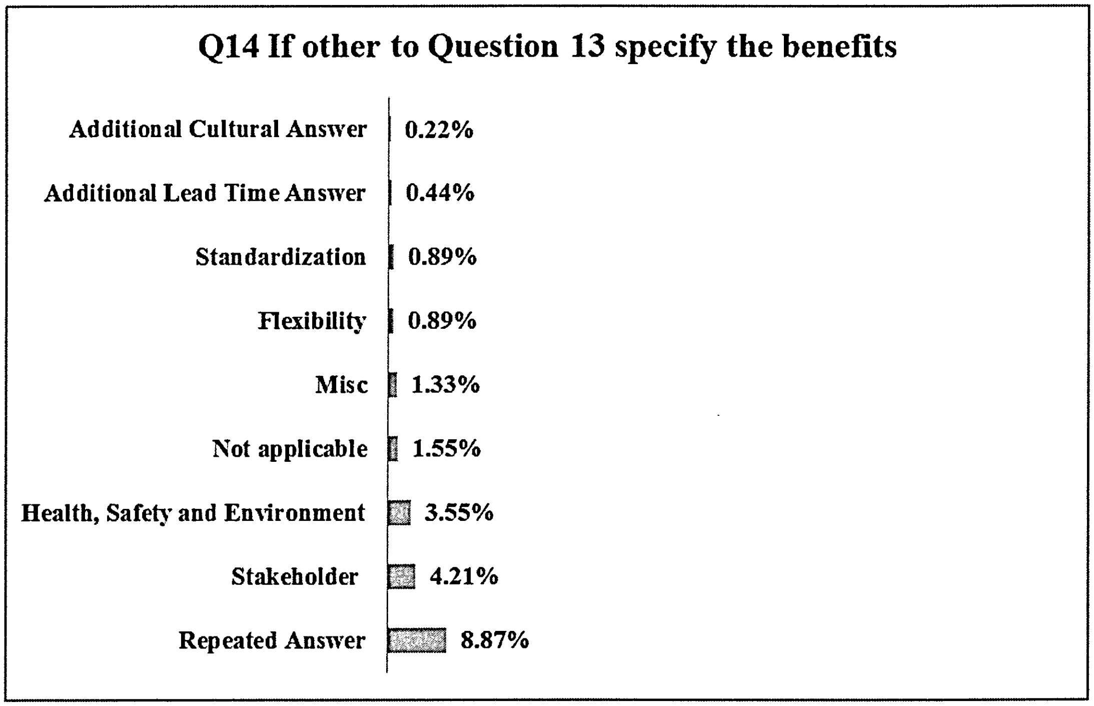


Figure 5.14: Additional Benefits Specified by Respondent (Optional)

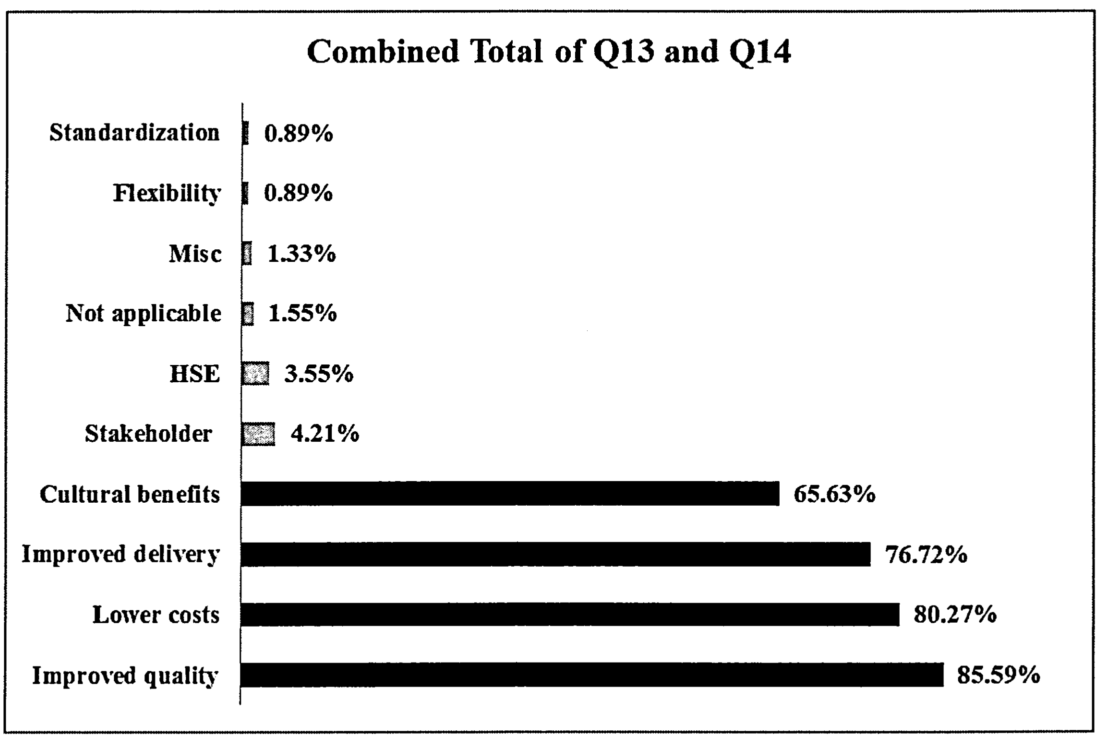


Figure 5.15: Combined Total of Q13 and Q14

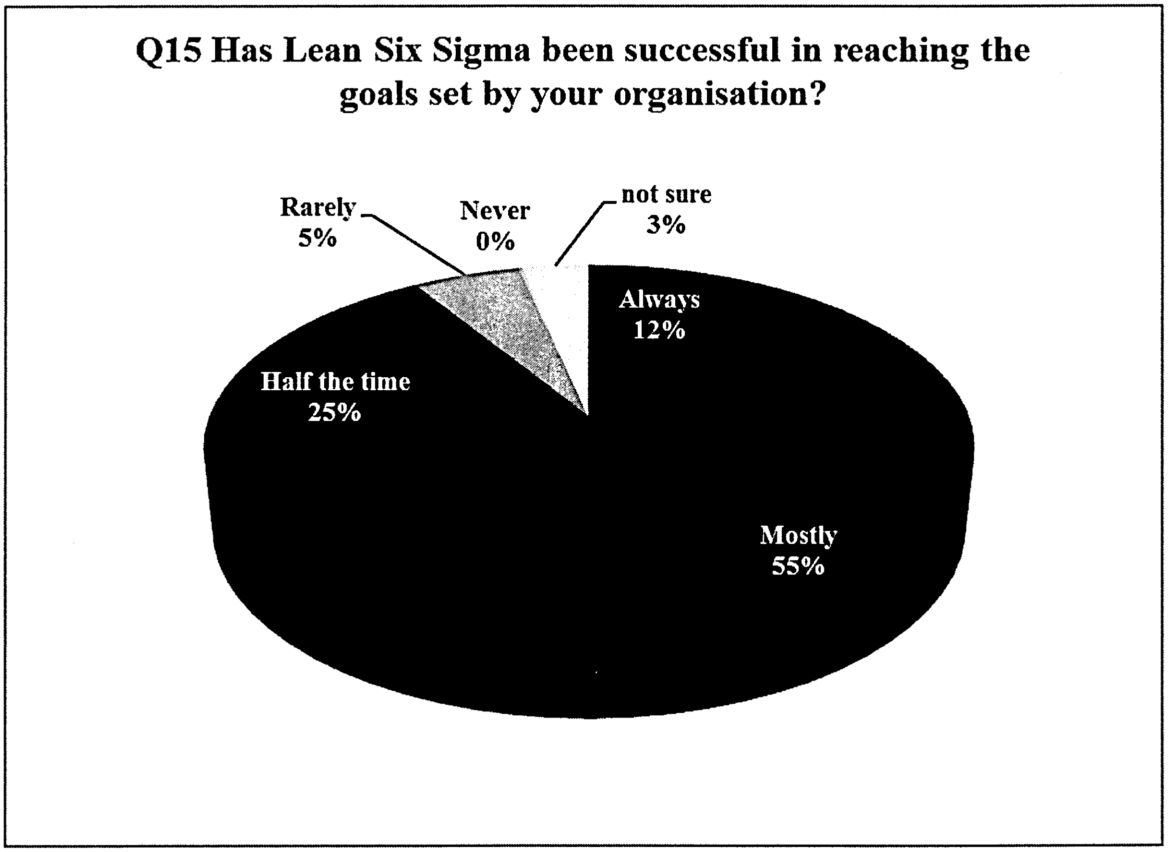


Figure 5.16: Respondent Success with using LSS to reach Organisation Goals

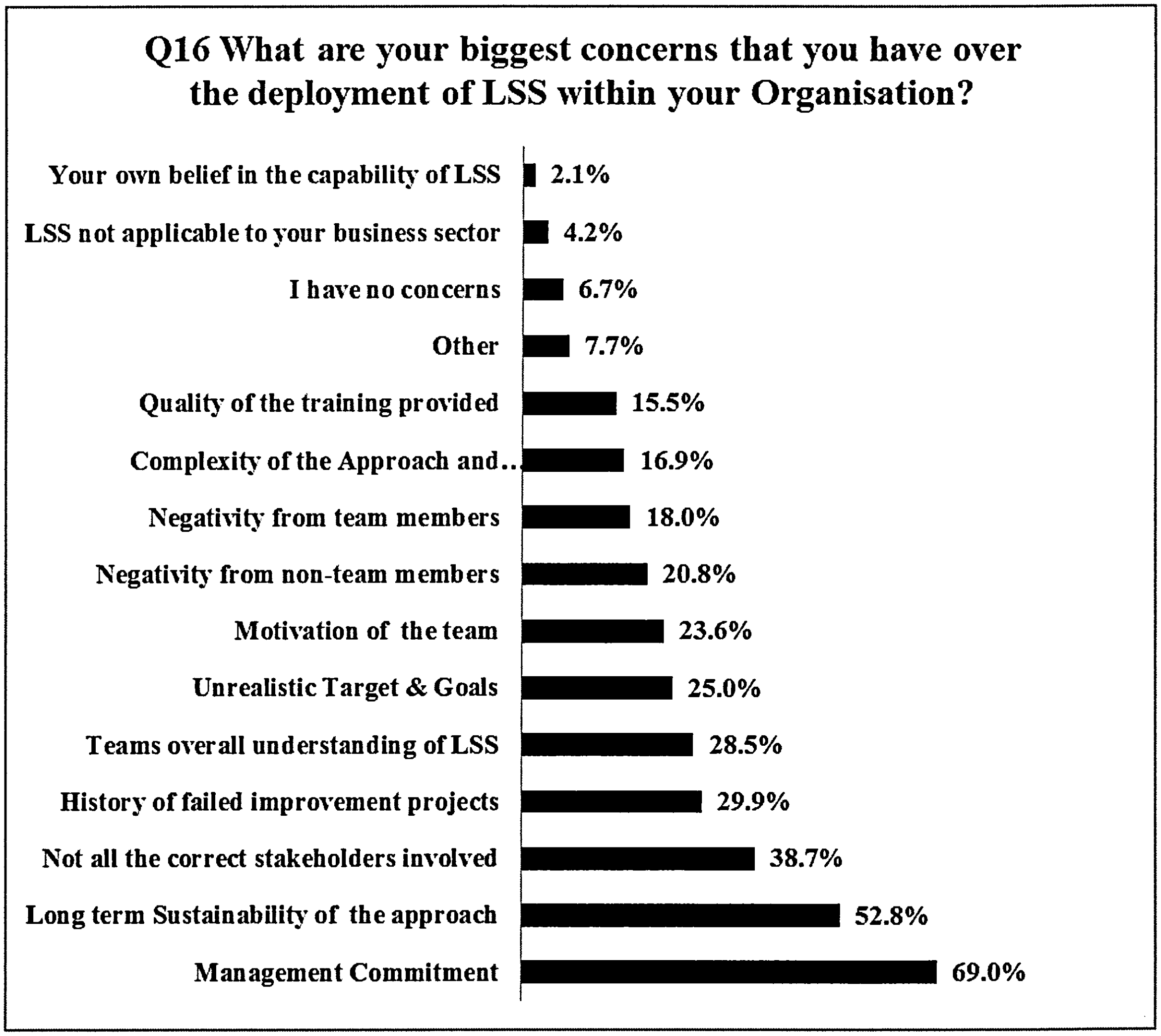


Figure 5.17: Respondents biggest Concerns from Deploying LSS

Answers from the other category for question 17 were of a very low response and consisted of repeated answers as listed in question 16 or open text that was not applicable.

5.1.6 Environmental Responses

The results depicted in Figure 5.18 to Figure 5.30 focus on the respondents experiences and beliefs of LSS in relation to the Environment. The responses clarify the environmental benefits and disadvantages from the use of LSS. These responses also clarify the awareness of the LSS community of the recent environmental or "Green" versions of Lean and/or Six Sigma.

Respondents also provide their opinions on the validity of combining LSS with EMS practices and their thoughts on increasing levels of environmental legislation for their organisation.

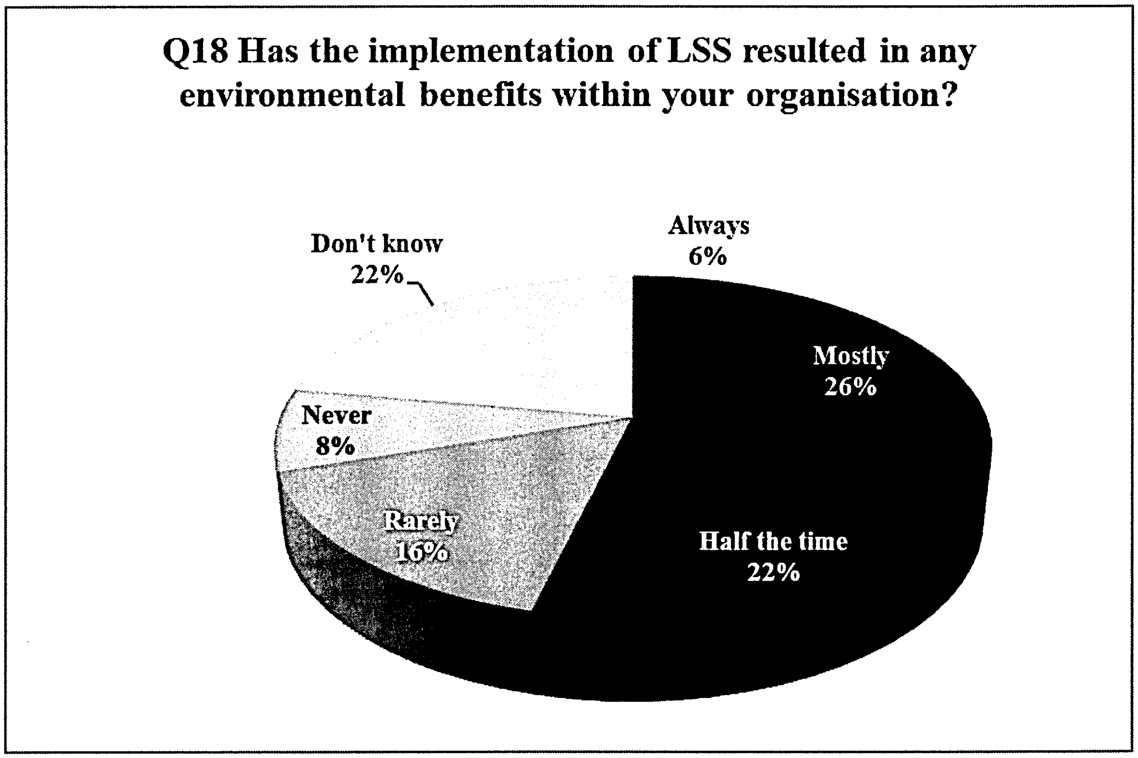


Figure 5.18: Respondent experience of environmental benefits from implementing LSS

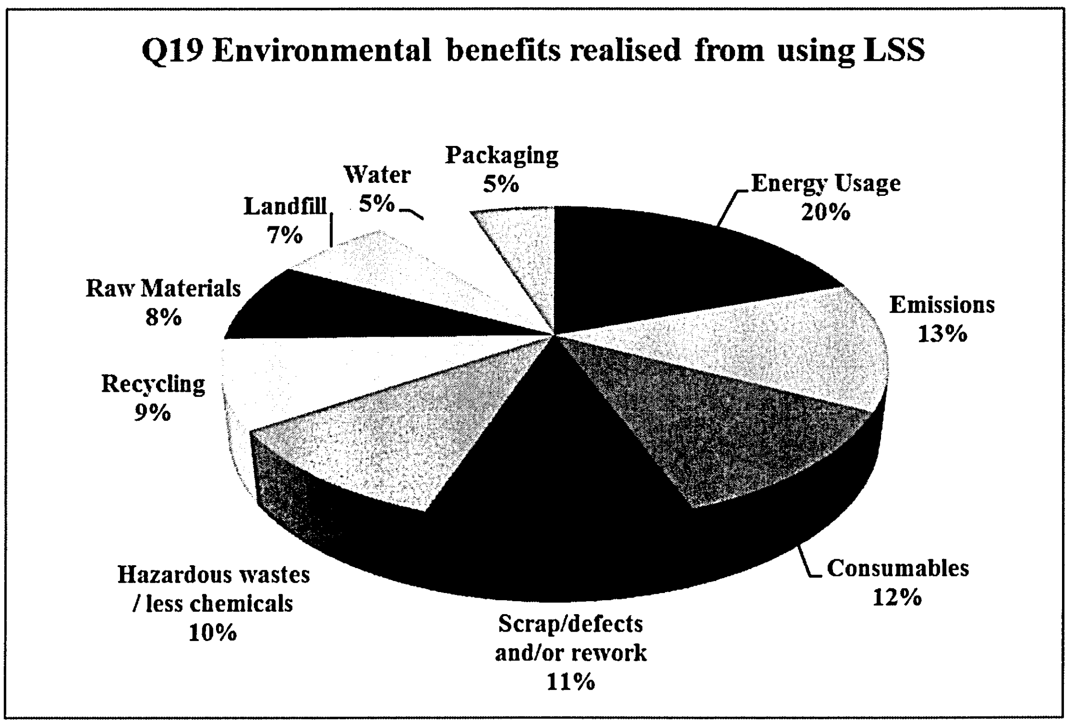


Figure 5.19: Respondents Specific Environmental Benefits from using LSS

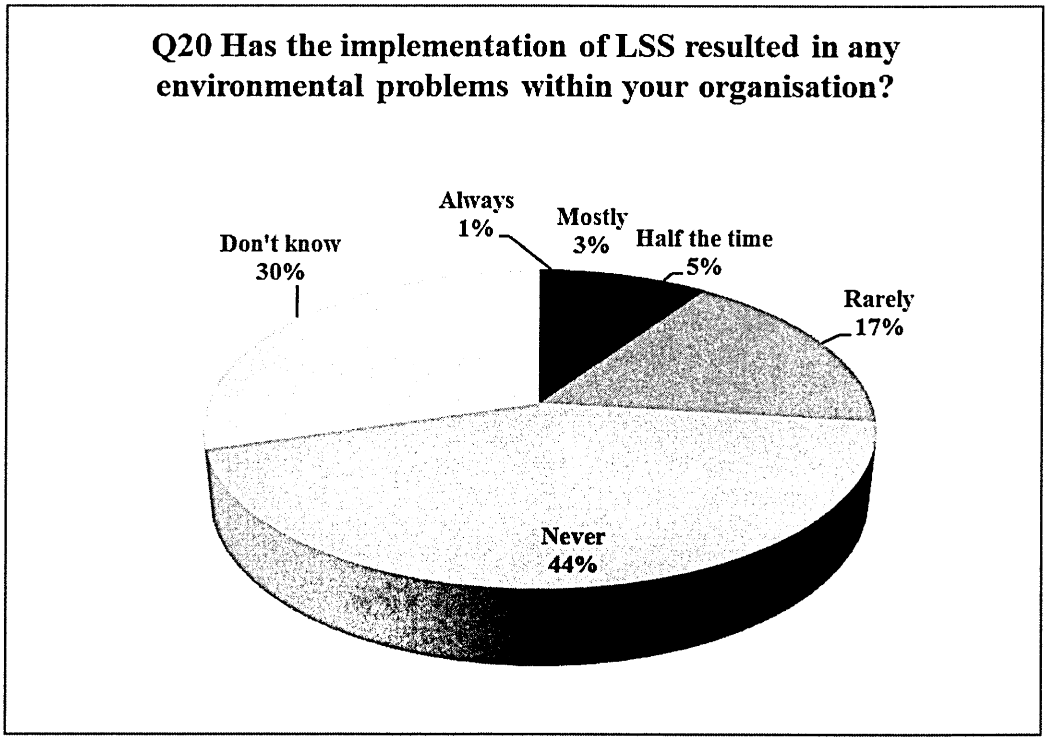


Figure 5.20: Respondents experiences of environmental problems with implementing LSS

The specific open text responses to question 21 regarding environmental problems experienced from using LSS can be found in Appendix F.1. In total 29 responses were provided for this question.

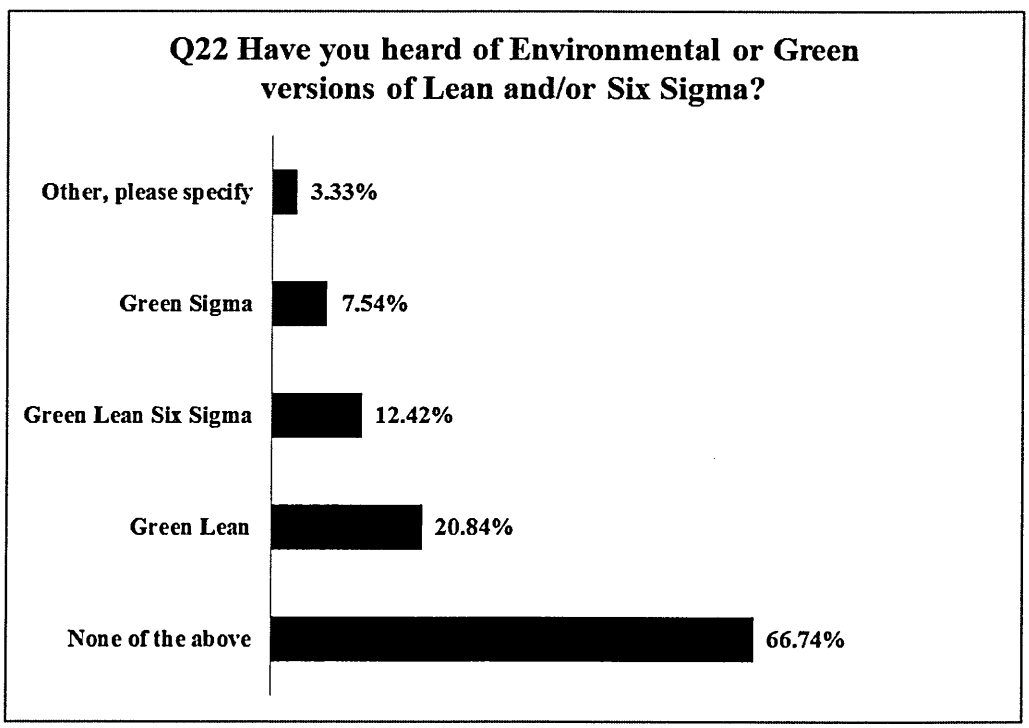


Figure 5.21: Respondent Awareness of Environmental versions of LSS

For question 23 which asked for the "other" responses from the previous question a total of 23 responses were made. These free text responses can be viewed in appendix F.2 but they did not yield any significant alternatives.

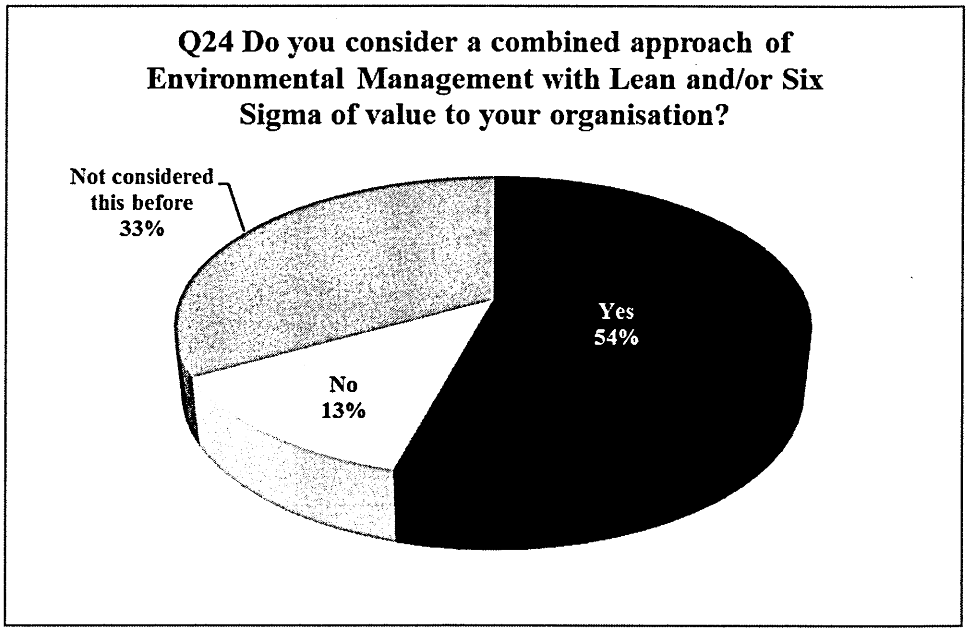


Figure 5.22: Respondents opinion on the value of combining LSS with Environmental Management

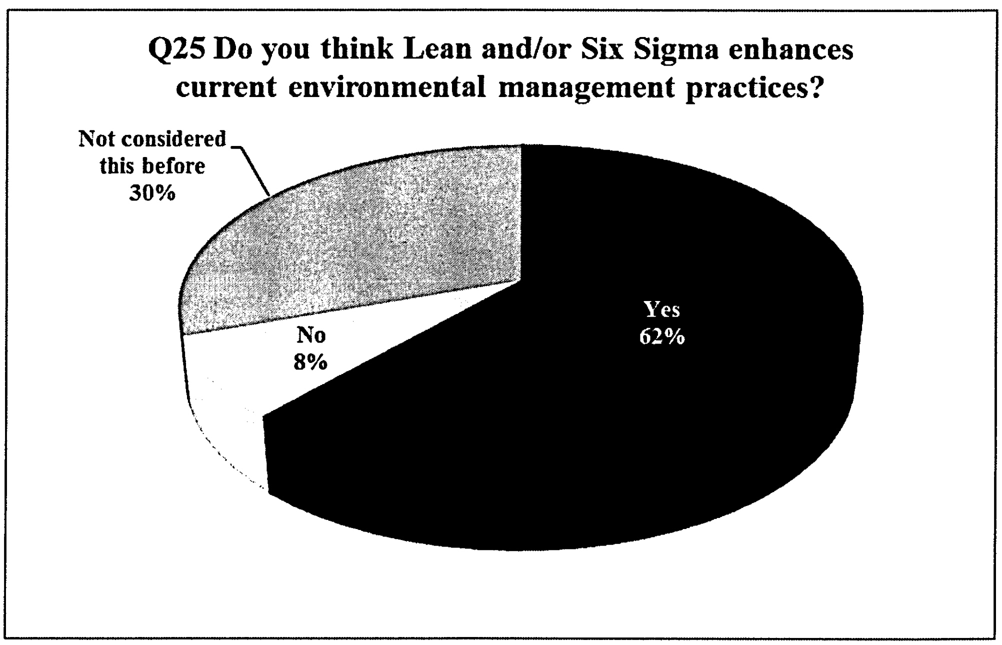


Figure 5.23: Respondents opinion of whether Lean and or Six Sigma enhances Environmental Management practices

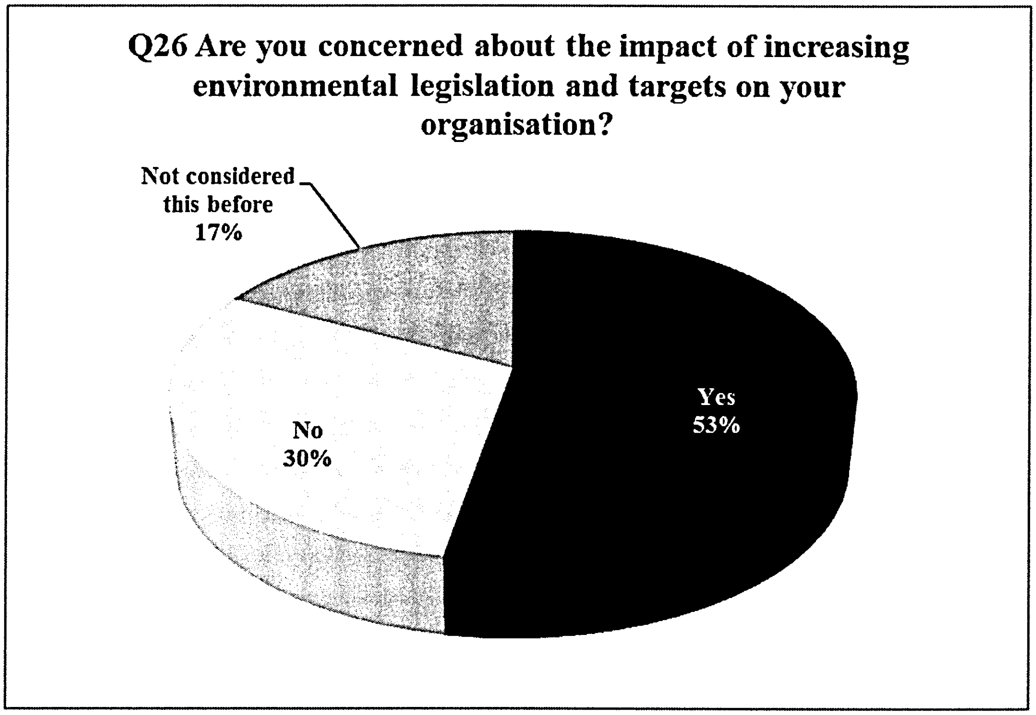


Figure 5.24: Respondent Concerns of Increasing Environmental legislation and targets on their Organisation

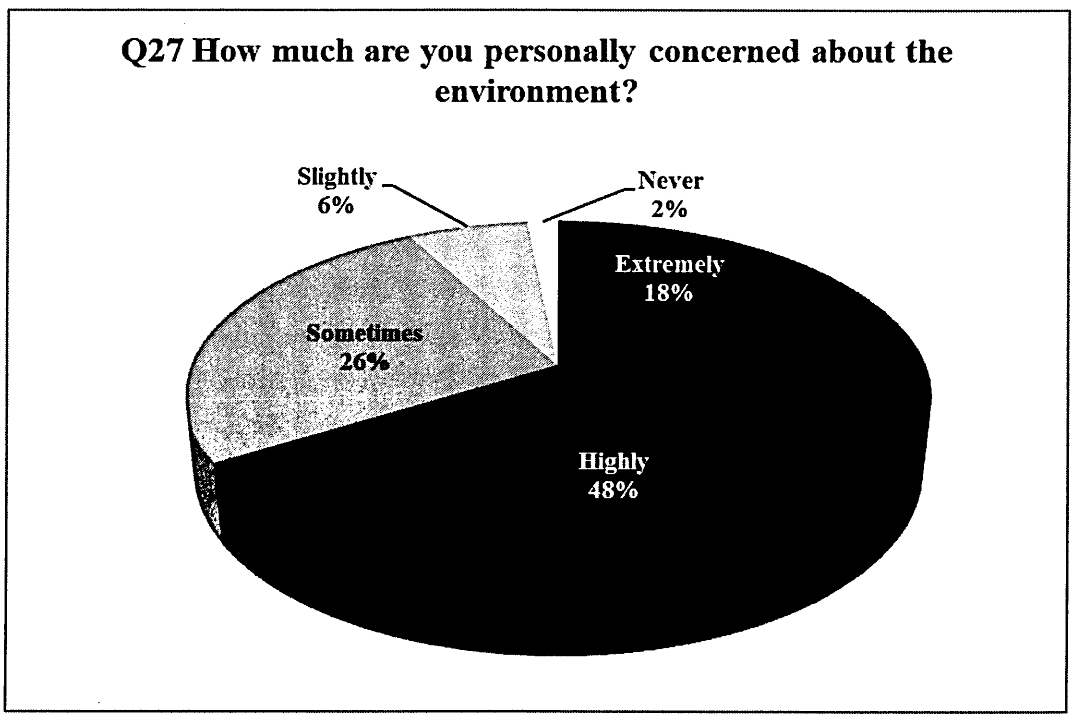


Figure 5.25: Respondents level of concern about the Environment

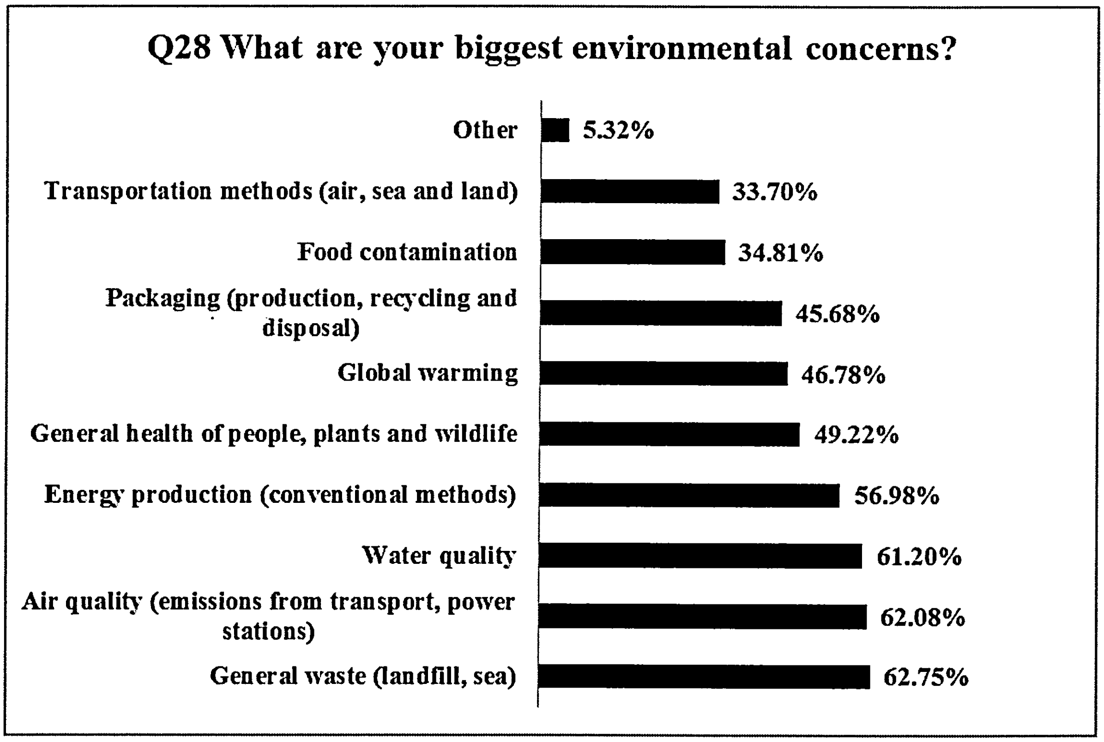


Figure 5.26: Respondents biggest Environmental Concerns

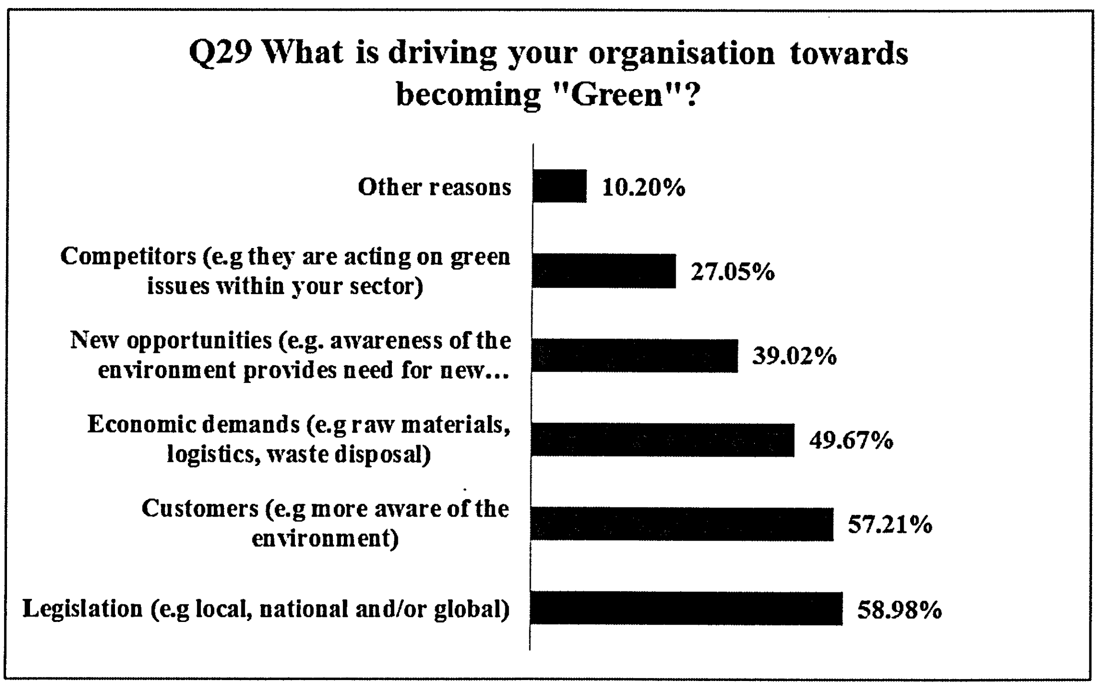


Figure 5.27: Key drivers for respondent organisations to become “Green”

In question 30 other drivers for organisations to go "green" were provided by respondents if the drivers in question 29 were not applicable. In total 40 responses were provided and these open text answers can be found in appendix F.3.

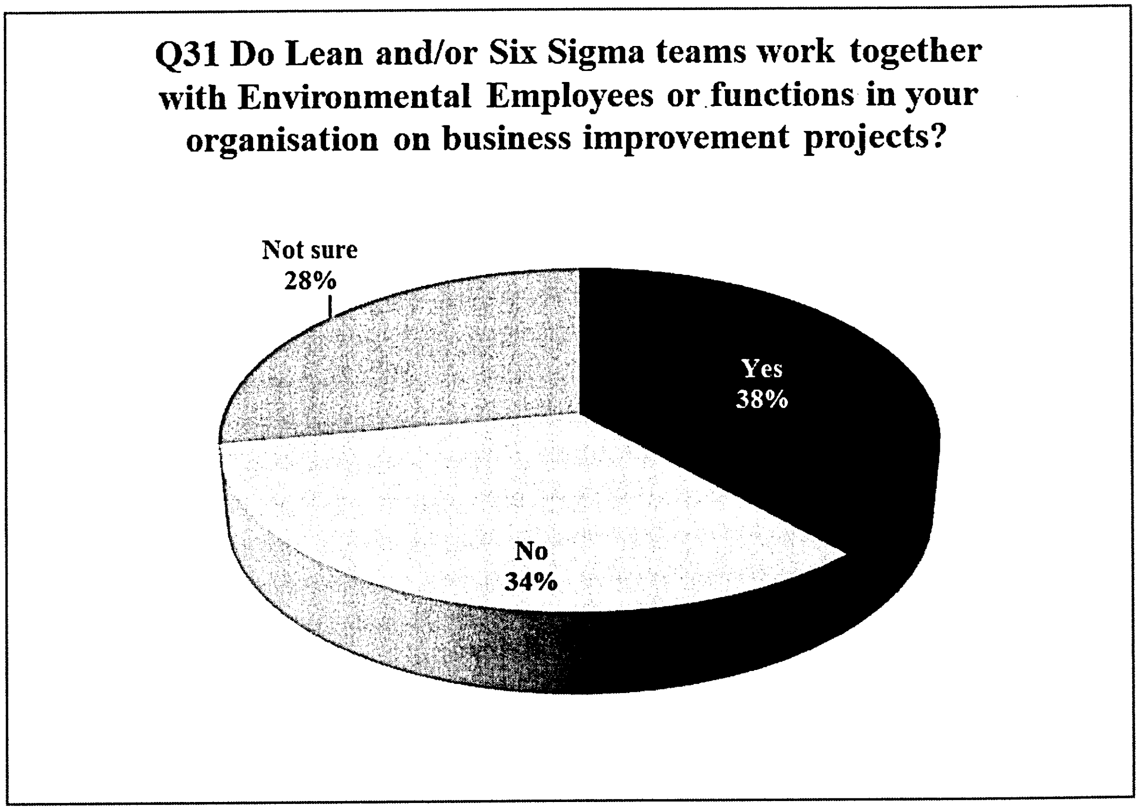


Figure 5.28: Respondents opinion on whether LSS teams work with Environmental employees on Business Improvement Projects

Question 32 gave the respondents the opportunity to voice their opinions as to why employees do not work together on business improvement projects. These answers relating to question 31 yielded 52 responses in total for the Global LSS community and can be viewed in appendix F.4.

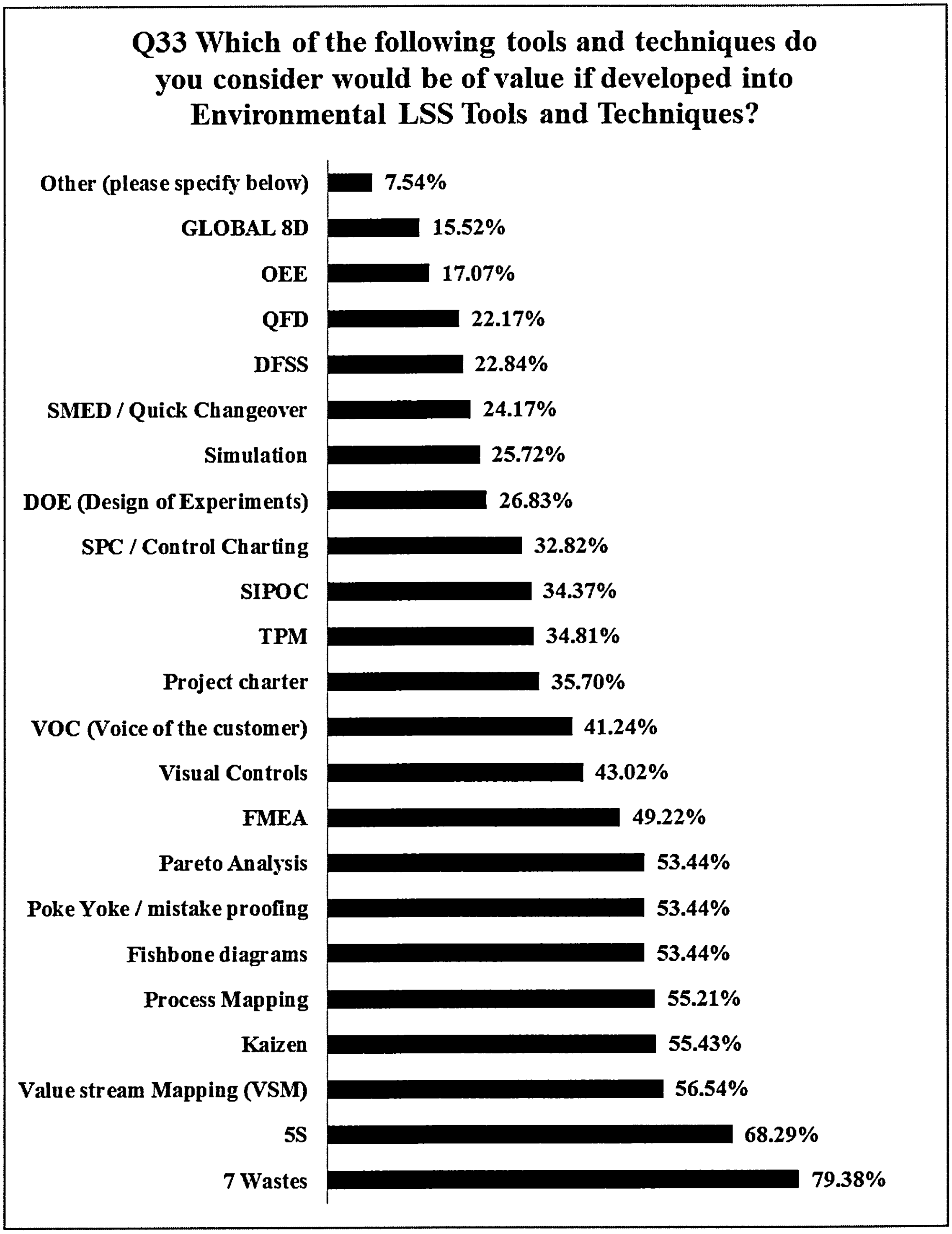


Figure 5.29: Respondents opinion on LSS tools and techniques that would be of value if developed into Environmental Versions

For question 34 LSS users were given the option of providing alternatives from those LSS tools supplied in question 33. A total of 29 responses resulted and these can be viewed in appendix F.5.

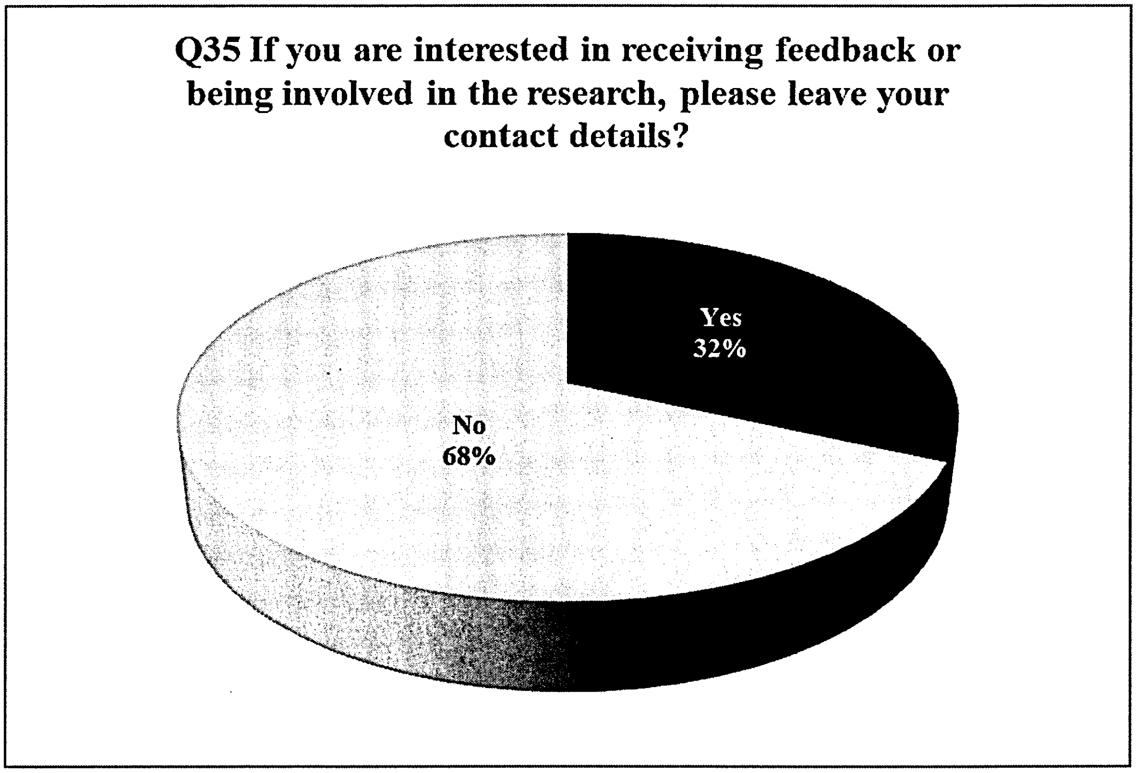


Figure 5.30: Respondents interested in feedback on the Research

5.2 Summary

The results provided by the survey provide a useful top level summary of the views of the global LSS community. These responses would next need be to be filtered using Excel by exporting the data from Snap Survey. In addition this data would need to be analysed critically using statistical techniques provided by Minitab.

6 Analysis of Global LSS Survey Results

6.1 Introduction

The objective at this stage of the research is to define from the outcomes of the analysis the core requirements for the ELSSSA tool and framework in the subsequent sections of the research and development. Businesses can be different in their core characteristics depending on their location, business sectors, employees and many other factors. Therefore by clarifying these differences and similarities empirically, it will be possible to develop a structured customer focused approach for organisations that are assessed using the framework.

The outcomes of this analysis will be vital during the development of the framework and the related tools and techniques and also be of value in the application phase. It will help identify statistically which elements of the framework can be generic by analysing when key characteristics do not differ. Where key characterises is statistically shown to be different bespoke elements of the ELSSSA framework will need to be developed.

The main body of this section will analyse the results from Section 5 and identify the statistically significant differences between the 5 following key areas: -

- Geographic Location
- Business Sector
- Company Structure
- LSS Role Type
- LSS Experience

6.2 Methodology

The Global LSS survey contains a range of question types which are analysed using two main types of statistical techniques. For questions types where the response is typically a yes/no answer (attribute data) these have been analysed using Chi-Squared calculations (Mantel 1963). Chi-square tests will be utilised to compare the relationship between 2 or more proportions (or percentages) against one other to determine if they are indeed statistically different.

The applied method used to conduct this type of analysis is described in detail in Appendix B.2.

For questions where a rating scale exists these questions (e.g. Q10) these will be analysed using Minitab's non-parametric data analysis tools. In the first instance the Kruskal-Wallis test (Siegel 1957) will be used determine if a statistical difference exist. This test is applicable to data that is of ordinal type (Feir-Walsh et al 1974). In this case the use of Kruskal-Wallis will allow for the comparison of medians from the different samples of data that use ratings scales.

This type of analysis is sometimes viewed as inferior to parametric data analysis however if large sample sizes (excess of 100) can be obtained, as in the case of this research then non-parametric data analysis using a method such as Kruskal-Wallis is still seen as powerful and worthwhile (Zimmerman 1993)

In cases where a significant effect is found, further analysis will be conducted using the Mann-Whitney test (Milton 1964). The main reason for this is that in cases where there are more than 2 samples of data to be analysed, Kruskal-Wallis will inform that a statistical difference exists but it will not specify which sample this difference lies. Mann-Whitney tests in Minitab assist to clarify where specifically the statistical difference lies by performing testing on 2 samples at a time. The application of the Kruskal-Wallis and Mann-Whitney is described in full detail in Appendix B.3 and B.4.

For each of the 5 selected categories a matrix table was developed (for examples see Table 6.2) within Excel which depicts which questions were to be cross tabulated and the statistical technique employed. In addition for each of the 5 selected factors tested an analysis of results summary table has been created which can be viewed at the end of each factor analysed (for example see Table 6.4). This clarifies whether the result of each individual test was statistically significant and the related p-values (Rice 1998).

6.3 Data Validation

The data returns were checked through by the researcher during the results phase in Section 5 for any strange or deliberately false returns but overall were excellent and only 1 of the 451 returns was removed. Before the analysis could take place it was necessary to assess the data in question 10 regarding experience of LSS users. There were a total of 23 respondents who stated that they had never used Lean and/or Six Sigma. As the objective of the survey was to get the opinions of actual LSS users it was deemed necessary to remove these responses from the analysis as these could potentially impact the overall results and subsequent development and testing of the ELSSA framework and tools. This left a total sample size for analysis of 427 LSS users.

6.4 Geographic Location (Q5) Analysis

Of the 427 responses from the 7 global locations, the vast majority of the sample came from 3 global locations namely North America, Europe and Asia. This section will focus primarily on these 3 global locations as they provide a statistically sufficient sample size return for the purposes of this analysis. This leaves a total of 400 responses (93.6%) from the 427 responses for the 7 global locations available. The remaining sample size quantity for the three geographic locations is summarised in the Table 6.1 below: -

Company Location	Sample Qty (n)
North America	179
Europe	136
Asia	85
Sum	400

Table 6.1: Major geographic location sample returns

Questions from the LSS survey were subsequently selected which were judged to be of potential value to the research when cross tabulated with geographic location. These questions, related hypothesis and statistical testing method are summarized in Table 6.2.

Geographic Location Analysis Matrix			
Q5	Company Location - Asia, Europe and USA	Objective	Statistical Technique
Q7	Which Business Sector is your organisation from?	To determine if the proportion of use of LSS by geographic location and business sector is the same	Descriptive statistics, Cross Tabulation and Chi Square
Q10	How long have you been using the Lean and/or Six Sigma approaches?	Is the maturity of LSS the same in different geographic locations	Kruskal Wallace and Mann-Whitney Tests
Q15	Has Lean and or Six Sigma projects been successful in reaching the goals/expectations of your organisation?	To determine if different geographic locations have the same scale of benefits from deploying LSS	Kruskal Wallace and Mann-Whitney Tests
Q16	What are your the biggest concerns that you have over the deployment of Lean and/or Six Sigma within your organisation?	Do different geographic location have the same concerns over the deployment of LSS	Descriptive statistics, Cross Tabulation and Chi Square
Q18	Has the implementation of Lean and/or Six Sigma resulted in any environmental benefits within your organisation?	Do different geographic locations view the Environmental benefits of LSS to the same level	Kruskal Wallace and Mann-Whitney Tests
Q20	Has the implementation of Lean and/or Six Sigma resulted in any environmental problems within your organisation?	Do different geographic locations view the Environmental negatives of LSS to the same level	Kruskal Wallace and Mann-Whitney Tests
Q22	Have you heard of Environmental or Green versions of Lean and or Six Sigma, please tick those that apply?	Is the understanding of Green LSS the same in different geographic locations	Descriptive statistics, Cross Tabulation and Chi Square
Q24	Do you consider a combined approach of Environmental Management with Lean and/or Six Sigma of value to your organisation?	Do different geographic locations view the combined use of Environmental Management and LSS of value in their organisation the same	Descriptive statistics, Cross Tabulation and Chi Square
Q25	Do you think Lean and/or Six Sigma enhances current environmental management practices?	Do different geographic locations view that LSS enhances current environmental practices the same	Descriptive statistics, Cross Tabulation and Chi Square
Q26	Are you concerned about the impact of increasing environmental legislation and targets on your organisation?	Do different geographic locations view the impact of increasing environmental legislation the same	Descriptive statistics, Cross Tabulation and Chi Square
Q27	How much are you personally concerned about the environment?	Do different geographic locations have the same level of personal concern for the environment.	Kruskal Wallace and Mann-Whitney Tests
Q28	In general are your biggest environmental concerns, please tick all that apply?	To determine if the environmental concerns across different geographic location are the same	Cross Tabulation and Chi Square
Q29	What is driving your organisation towards becoming "Green", please tick all those that apply?	To identify if the key drivers to go green the same in different geographic locations	Cross Tabulation and Chi Square
Q31`	Do Lean and/or Six Sigma teams work together with Environmental employees or functions in your organisation on business improvement projects?	Determine if different geographic locations have the same level of LSS and environmental employees working together on BIP.	Cross Tabulation and Chi Square
Q33	Which of the following tools and techniques do you consider would be of value if developed into Environmental or Green Lean Six Sigma tools and techniques, please tick all that apply?	To determine if the LSS tools deemed to be of value when developed into "Green "LSS Tools are the same by different geographic locations	Cross Tabulation and Chi Square

Table 6.2: Geographic Location Analysis Matrix

Business Sector Type (Q7)

The first question to be analysed and cross tabulated using Minitab was the business sector type of the LSS respondents in relation to global location. From the data returned, the highest response by far was from the manufacturing sector (29.5%). In total there were responses from 23 different sectors plus an additional category labelled as others. However due to the small sample size from all sectors apart from manufacturing it was necessary to group these together the sector types for this analysis.

All of the business sectors which could be deemed as manufacturing (food, automotive etc.) were grouped together and the same was repeated for the service sectors (e.g. governmental, healthcare etc.). This gave a sufficient sample size for the manufacturing sector of 225 (56.25%) and for the service sector 142 (35.5%). There were 33 (8.25%) responses that were classified as other which could not be related to either manufacturing or service sectors so these were therefore omitted from this analysis.

The resulting filtered data was subsequently exported to Minitab for analysis. A description of the method for cross tabulations and Chi-Square tests can be found in appendix B.2.

From the results in appendix table C.1 it can be seen that a p-value of 0.003 is recorded from this analysis and this demonstrates that there is a significant statistical difference (p-value <0.05) between the 3 geographic locations. The data percentages show that the USA has 70.59% of its users from the manufacturing Sector, whilst in both Europe (53.23%) and Asia (53.42) they are both nearly identical in their distribution, therefore suggesting that the USA is different to both Asia and Europe.

This analysis is important in relation to the development of the ELSSSA framework as it is more likely that an organisation in the USA that uses LSS will be from the manufacturing sector, than in Europe and Asia. The potential reasons for the difference will be explored further in section 7.2.2 which will focus on cross tabulation of business sector and other key questions in the survey.

Duration of LSS use in the workplace (Q10)

The aim from this analysis is to clarify if the different global locations have been using Lean and/or Six Sigma for the same amount of time statistically. As the responses were in the form of a scale non parametric data Kruskal-Wallis tests were performed to conduct this analysis.

Initially the filtered data from the Excel spreadsheet was sorted by the duration that the LSS respondents had been using Lean and or Six Sigma. These results are presented in the Table 6.3.

	Company Location		
Q10 How long have you been using the Lean and/or Six Sigma approaches?	**Asia**	**Europe**	**North America**
I have never used Lean and/or Six Sigma	**11.34%**	**4.23%**	**3.24%**
6 Months or less	**6.19%**	**7.75%**	**3.78%**
7-12 Months	**6.19%**	**4.23%**	**3.78%**
1-2 Years	**18.56%**	**9.15%**	**11.89%**
2-5 Years	**27.84%**	**27.46%**	**27.57%**
5-10 Years	**19.59%**	**29.58%**	**21.62%**
10 Years +	**10.31%**	**17.61%**	**28.11%**

Table 6.3: Duration of LSS Experience

The data also implies that LSS is longer established in the USA than Europe and Asia overall with 28.11% having more than 10 years' experience (Europe has 17.61% and Asia 10.31%). However further more detailed analysis is necessary to show whether any of the three locations is statistically different to the others.

In order to analyse the data statistically in Minitab the data would need to be changed to a rating scale. The scale therefore for example replaces the response in Q10 of 0-6 months experience of LSS to a 1 and someone with 7-12 months to a 2 and so on. This type of method will be used on other questions in the analysis section that employ the Kruskal-Wallis and Mann-Whitney tests.

In Excel the data was changed to a rating scale using the filter function and this data is inserted into the worksheet in Minitab. The data in Minitab is analysed initially using the boxplot function and is depicted in Figure 6.1.

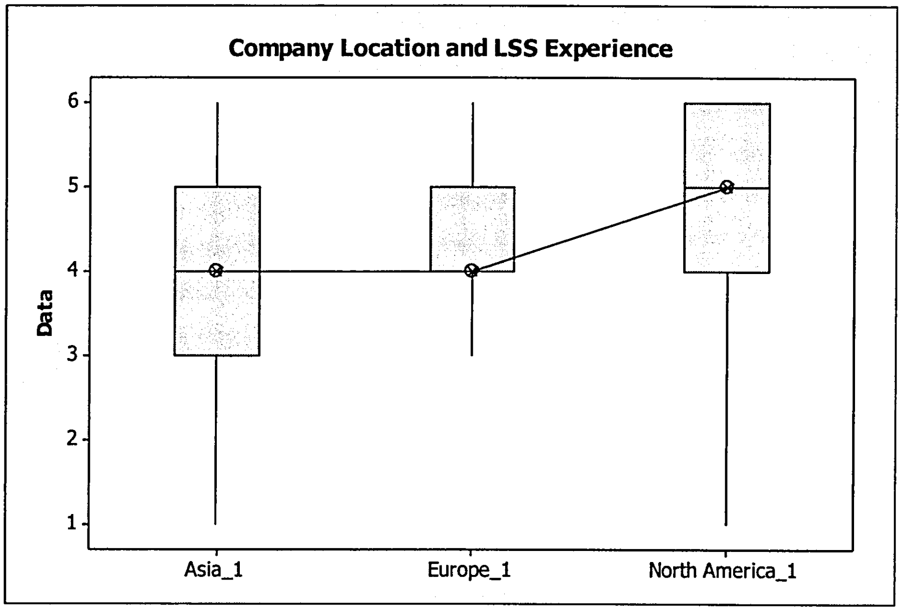


Figure 6.1: Global Location and LSS Experience

As this is data contain a rating scale Kruskal-Wallis and Mann-Whitney non parametric analysis tools should be used within Minitab. These allow for analysis of data containing medians rather than mean values. A description of the method employed to conduct the Kruskal-Wallis tests can be found in appendix B.3

The Kruskal-Wallis Test indicated that there was potentially a significant difference between the three geographic locations and the duration that users had experience of LSS with an overall p-value of 0.043 (appendix table C.2).

Secondary analysis was therefore required using the Mann Whitney test to clarify which of the global locations was statistically different. This involved performing test on two global locations at a time. A description of the method used to conduct these tests can be found in appendix B.4

From these tests (appendix table C.3) it can be concluded that both North America and Europe are statistically different in terms of duration of experience than Asia. They both have longer experience of the LSS approach than Asia; however it can be concluded that statistically both the USA and Europe are the same in terms of duration experience.

Success of Lean and / or Six Sigma Projects in reaching company goals (Q15)

Analysis conducted (appendix table C.4) using the Kruskal-Wallis test resulted in a p-value of 0.250 (adjusted for ties), i.e. there was no significant difference between the level of success achieved by LSS users in organisations from Asia, Europe and the USA. The respondents overall were very positive about the benefits achieved from their projects with a median of 4 recorded for all 3 global locations.

Biggest Concerns over the deployment of LSS in the Organisation (Q16)

The aim here of these tests was to explore if LSS users from different global locations had the same concerns over the deployment of LSS in their organisation. Of the 15 different concern types this analysis (appendix table C.5) focuses on the top 5 concerns shown in Figure 5.17 . The Chi-Square test showed that the concerns over the deployment of LSS were all the same statistically except for the history of failed projects which gave a p-value of 0.051.This was followed up by paired Chi-Square tests to identify where the differences lay. The results (appendix table C.6) proved that the statistical difference was between Asia and the USA, with the USA reporting much higher concern over the history of failed LSS projects with their businesses than Asia.

Environmental Benefits of LSS (Q18)

The purpose of this analysis was to deduce whether the environmental benefits of LSS (Q18) were the same for LSS users of different ranges of LSS experience. Due to the 5 point rating scale employed (Never to Always) for the response it was necessary to utilise the Kruskal-Wallis technique for this analysis.

The tests (appendix table C.7) produced a p-value of 0.360 (adjusted for ties) therefore no statistical difference exists between the 3 global locations in relation to the environmental benefits of LSS experiences by the LSS users (see Figure 6.2).

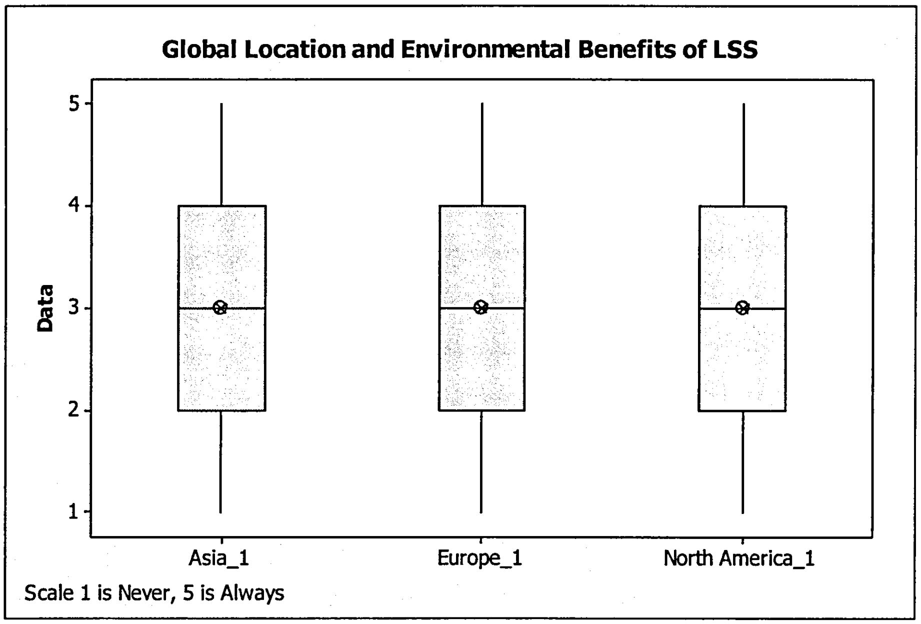


Figure 6.2: Global location and Environmental benefits of LSS

Environmental Negatives of LSS (Q20)

The Kruskal-Wallis tests that were conducted above were repeated for the environmental negatives achieved through the deployment of LSS (appendix table C.8), to explore if there was a statistical difference between the 3 global locations. The result indicated a p-value of 0.007 (when adjusted for ties) which indicated that the 3 global locations were statistically different and therefore it would be necessary to perform further tests using Mann-Whitney techniques to identify where this difference lies.

Initially a boxplot was created in Minitab's graph function to provide a possible insight to where the difference existed. The boxplot's graph in Figure 6.3 suggested that the difference between the 3 global locations existed within the LSS community in Asia.

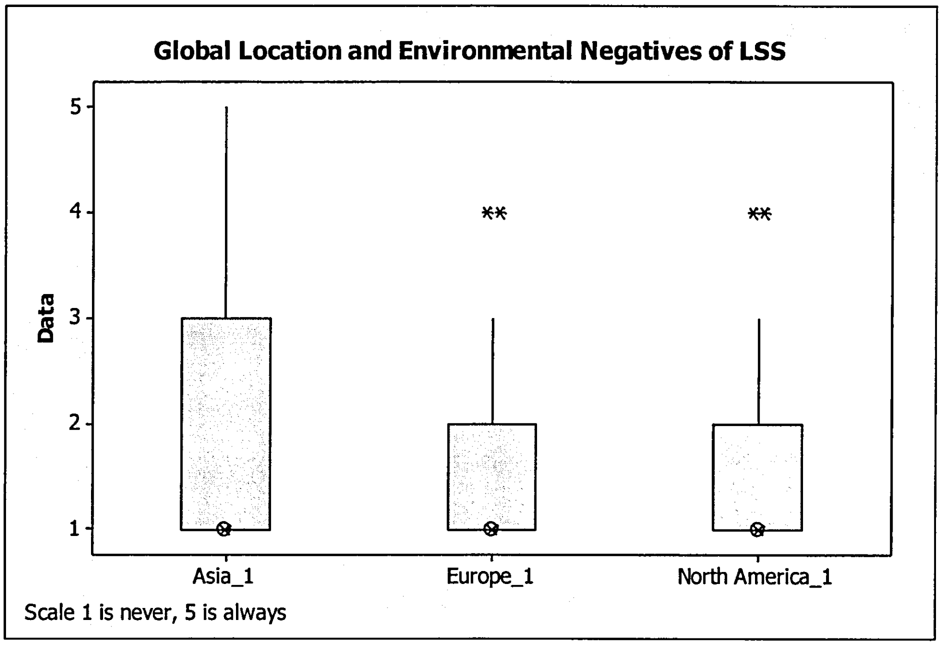


Figure 6.3: Global location and environmental negatives of LSS

Also worth noting in the boxplot, were the outliers present for Europe and the USA. However it would be foolish to assume these are data entry errors (Anscombe 1960). As discussed in Section 2.3.3 it is possible to experience environmental negatives from the deployment of LSS within an organisation. It may be highly unlikely that this occurs "most of the time" but it is possible that the risk is higher within certain industry types where chemicals and high degrees of transportation are used.

To confirm this statistically additional analysis was performed Mann-Witney tests (appendix table C.9). Tests performed between Asia and Europe and Asia and the USA clarified that they were statistically different however there is no statistical difference between Europe and the USA.

Overall the analysis suggests that Asia is more concerned about the negative environmental impact of LSS than their counterparts in Europe and the USA.

Knowledge of Green or Environmental Versions of Lean and /or Six Sigma (Q22)

The aim of this analysis was to identify whether users from the 3 different global locations have the same awareness of new "green" or environmental Lean and/or Six Sigma approaches (Q22). For this question respondents could choose any of the following 4 options regarding these new approaches.

1. Green Lean
2. Green Sigma
3. Green Lean Six Sigma
4. None of the above

Cross tabulation and Chi-Square test were performed for each of these options (appendix table C.10) to check if they were statistically the same, and there was no significant difference found between the Asia, Europe and the USA with p-values >0.05 for all tests concerned. Therefore knowledge of these new "green" approaches would appear to be the same across the 3 major global users of LSS.

Value from combined use of LSS and Environmental Management (Q24)

These Chi-Square tests examine if the combined use of LSS and environmental management was seen of value by the different global locations. This involved the Chi-square tests being performed on the respondent's data and this particular question provided the respondents with the option to respond to this question with the usual "no" or "yes" and in addition "not considered this before".

From the tests a p-value of 0.132 resulted (appendix table C.11) indicating that that there no statistical difference between the different global locations.

LSS enhancement of current Environmental Management Practices (Q25)

Cross tabulation and Chi-Square tests from this analysis examine if there is a statistical difference between the global locations and the use of LSS to enhance current environmental management practices. From these tests (appendix table C.12) it can be demonstrated that there is no statistical difference between these results with a p-value of 0.093. As a result no additional analysis was conducted as there was no significant difference for the enhancement of environmental management practices through the use of LSS by global location.

Impact of Increasing Environmental Legislation (Q26)

The following Chi-Square test (appendix table C.13) aimed to clarify if LSS users from the 3 global locations had the same concern statistically over the impact of increasing levels of environmental legislation within their organisation. The tests resulted in a non-significant p-value of 0.335 indicating that the responses from the 3 global locations were the same.

Personal concern level over the environment (Q27)

Cross tabulated tests were conducted on the respondents own personal concerns for the environment by global location. The aim was to determine if they had the same concerns across Asia, Europe and the USA.

As this particular question used a rating scale therefore a Kruskal-Wallis test was performed on the data and a significant p-value of 0.008 was attained when adjusted for ties. This indicated that there was a statistical difference between the 3 global locations. Using the graph function in Minitab, a boxplot was created (Figure 6.4) to pictorially explore any potential differences. The graph suggested there was indeed a difference between Asia and both Europe and the USA with Asia being highly concerned overall about the environment.

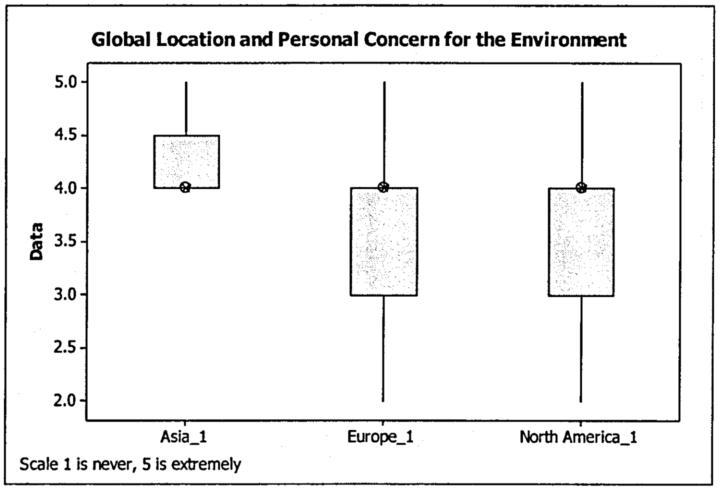


Figure 6.4: Global location and personal environmental concern levels

To test this prediction statistically Mann-Whitney tests (appendix table C.15) were performed. The 1st test examined Asia and Europe and this identified that there was a significant difference between the two locations and this was also the case for Asia and the USA. When the test was performed for Europe and the USA, no significant difference were found between these 2 global locations.

Types of Environmental Concern (Q28)

This series of statistical tests examined the top 5 Environmental concerns of the global LSS community across the 3 global locations. The Chi-Square tests (appendix table C.16) proved that statistically there is no difference between the global locations for 2 of the concerns (energy production and general health of people, animals etc.).

Statistical difference did exist for the 3 other top 5 concerns for the different global locations examined. The LSS community in Asia (appendix table C.17) is clearly less concerned (51.76%) about the impact of general waste for land and sea when compared to Europe (67.16%) and the USA (68.72%). Here a p-value of 0.022 resulted clarifying that a significant statistical different does exist between the global locations.

The 2nd highest environmental concern overall globally was for air quality. The Chi-Square tests (appendix table C.18) showed that a statistical difference existed with this sample data with a p-value of 0.025. From the tabulated statistics it can be seen that within Europe 53.68% of the population thought that air quality was a high concern this compares to the USA (66.48%) and Asia (69.41%). This suggests that Europe is less concerned that both Asia and the USA about air quality as an environmental issue.

The 3rd highest environmental concern for the global LSS community was the quality of water. The Chi-Square tests (appendix table C.19) resulted in a very low p-value of 0.001 meaning that a statistical difference exists between the 3 global locations examined. From the tabulated statistics it clearly suggests Europe is much less concerned about water quality (45.59%) when compared to Asia (68.24%) and the USA (70.95%).

Key organisation drivers towards going "Green" (Q29)

Chi-Square tests (appendix table C.20) were performed on the key drivers towards going "green cross tabulated with Asia, Europe and the USA. Of the 5 different driver options, 4 were statistically the same however there was a difference identified regarding legislation where a p-value of 0.007 was recorded.

It can be seen from the tabulated statistics that the LSS respondents from Europe (70.59%) view legislation as a more important driver for going "green" in comparison to that of Asia (54.12%) and the USA (54.75%).

LSS and environmental employees working together on Business Improvement Projects (Q31)

This analysis (appendix table C.21) aimed to determine if the different global locations have the same percentage of LSS and environmental employees working together on business process improvement projects in the respondent organisation.

The responses from Asia produced 65.63% whilst in USA 57.03% and the lowest being from Europe with 40.21%. From conducting cross tabulation and Chi-Square tests these clarified that there was a statistical difference between the 3 global locations (p-value = 0.003).

Value of developing Green or Environmental Versions of LSS tools and techniques (Q33)

From the results in Figure 5.29 it has been identified that demand for certain "Green" LSS tools are very high with 7 Wastes achieving 79.38% from the LSS respondents and 5S 68.28%. Using Chi-square tests the demand for these tools would be analysed by geographic location to highlight whether this demand is statistically the same across Asia, Europe and North America.

This question had responses for 22 different "Green" LSS tools and techniques. For the purposes of the research it was deemed of value to analyse the top 5 of these potential tools as this is where the demand was highest. Therefore respondent data for "Green" versions of 7 Wastes, 5S, VSM, Kaizen and process mapping would be analysed in these statistical tests.

The Chi-Square test responses for "Green 7 Wastes" (appendix table C.22) yielded a p-value of 0.119 indicating that there is no statistical difference between the 3 global locations.

The same tests were repeated for "Green 5S" (appendix table C.23) and the resulting non-significant p-value demonstrated that there was no difference in the responses that had been collated from this study for Asia, Europe and the USA.

The 3rd highest overall response in terms of LSS tools and techniques deemed of value when developed was "Green VSM". From the test responses (appendix table C.24) Europe was in favour 61.76% and USA 60.89% this compared to just 45.88% in Asia. The Chi-Square tests yielded a p-value of 0.040 therefore it can be concluded that a statistical difference exists between these 3 samples; with Asia having a lower demand than Europe and USA for "Green VSM".

Chi-Square tests performed on the respondents views on "Green Kaizen" (appendix table C.25) demonstrated that no statistical difference exists between the USA, Asia and Europe with a p-value of 0.137.

Regarding the responses garnered for "Green process mapping" (appendix table C.26) the highest percentage was gained from Europe with 61.36%, followed by USA with 58.66% whilst Asia gave the lowest result with 51.16%. The subsequent Chi-Square tests p-value of 0.320 demonstrated that there was no statistical difference from these test results.

6.4.1 Geographic Location Analysis Results Summary

The pertaining results for this section of analysis by geographic location are summarized in the Table 6.4.

Geographic Location Analysis Results

Q5	Result	P-Value
Q7	Asia and Europe are statistically the same, the USA is different having a higher proportion of LSS users in the manufacturing sector than the service sector	0.003
Q10	USA and Europe are the same, Asia is statistically different (lower)	0.043
Q15	Statistically the same	0.250
Q16	Initial analysis chi-square History of failed projects is statistically different with Asia and USA, USA has higher concern	0.019
Q18	Statistically the same	0.360
Q20	Asia is statistically different from both Europe and USA. Asia view it more likely that negative consequences will occur through the use of LSS	0.007
Q22	Statistically the same	0.344 to 0.673
Q24	Statistically the same	0.132
Q25	Statistically the same	0.093
Q26	Statistically the same	0.335
Q27	Both Europe and USA are statistically the same however Asia is statistically different from both the USA and Europe, a having a higher personal concern for the environment	0.008
Q28	Asia is statistically less concerned about general waste (Landfill and sea) than Europe and the USA. Europe is statistically less concerned about air quality than Asia and USA. Europe is statistically less concerned about water quality than Asia and USA	0.022 for General Waste 0.025 for Air Quality 0.000 Water Quality
Q29	Europe is statistically more concerned about increasing legislation as a driver towards going green.	0.007
Q31`	Europe, Asia and USA are statistically different from each other	0.003
Q33	VSM is the only tool that is statistically different in term of demand by geographic location, it is seen as a lesser requirement in Asia	0.040

Table 6.4: Geographic Location Analysis Results

6.5 Business Sector Analysis (Q7)

As discussed in section 6.4 with the cross tabulation analysis with the industry sectors it was necessary to sort the responses into either manufacturing or service sectors. The aim of this section will be to determine if there are any statistically significant differences between the different industry sectors when cross tabulated to a selection of key questions supplied to the respondents in the survey. This analysis employs a mixture of Chi-Square tests and Kruskal-Wallis/Mann-Witney test methods.

These tests, the questions, objectives and statistical techniques are summarised in the business sector analysis matrix depicted in Table 6.5 below: -

Business Sector Analysis Matrix

Q7	Business Sector - Manufacturing and Service	Objective	Statistical Technique
Q10	How long have you been using the Lean and/or Six Sigma approaches?	Is the maturity of LSS the same in different business sectors	Kruskal Wallace and Mann-Whitney Tests
Q15	Has Lean and or Six Sigma projects been successful in reaching the goals/expectations of your organisation?	To determine if different business sectors have the same scale of benefits from deploying LSS	Kruskal Wallace and Mann-Whitney Tests
Q16	What are your the biggest concerns that you have over the deployment of Lean and/or Six Sigma within your organisation?	Do different business sector have the same concerns over the deployment of LSS	Descriptive statistics, Cross Tabulation and Chi Square
Q18	Has the implementation of Lean and/or Six Sigma resulted in any environmental benefits within your organisation?	Do different business sectors view the Environmental benefits of LSS to the same level	Kruskal Wallace and Mann-Whitney Tests
Q20	Has the implementation of Lean and/or Six Sigma resulted in any environmental problems within your organisation?	Do different business sectors view the Environmental negatives of LSS to the same level	Kruskal Wallace and Mann-Whitney Tests
Q22	Have you heard of Environmental or Green versions of Lean and or Six Sigma, please tick those that apply?	Is the understanding of Green LSS the same in different business sectors	Descriptive statistics, Cross Tabulation and Chi Square
Q24	Do you consider a combined approach of Environmental Management with Lean and/or Six Sigma of value to your organisation?	Do different business sectors view the combined use of Environmental Management and LSS of value in their organisation the same	Descriptive statistics, Cross Tabulation and Chi Square
Q25	Do you think Lean and/or Six Sigma enhances current environmental management practices?	Do different business sectors view that LSS enhances current environmental practices the same	Descriptive statistics, Cross Tabulation and Chi Square
Q26	Are you concerned about the impact of increasing environmental legislation and targets on your organisation?	Do different business sectors view the impact of increasing environmental legislation the same	Descriptive statistics, Cross Tabulation and Chi Square
Q27	How much are you personally concerned about the environment?	Do different business sectors have the same level of personal concern for the environment.	Kruskal Wallace
Q28	In general are your biggest environmental concerns, please tick all that apply?	To determine if the environmental concerns across different business sectors are the same	Cross Tabulation and Chi Square
Q29	What is driving your organisation towards becoming "Green", please tick all those that apply?	To identify if the key drivers to go green the same in different business sectors	Cross Tabulation and Chi Square
Q31`	Do Lean and/or Six Sigma teams work together with Environmental employees or functions in your organisation on business improvement projects?	Determine if different business sectors have the same level of LSS and environmental employees working together on BIP.	Cross Tabulation and Chi Square
Q33	Which of the following tools and techniques do you consider would be of value if developed into Environmental or Green Lean Six Sigma tools and techniques, please tick all that apply?	To determine if the LSS tools deemed to be of value when developed into "Green "LSS Tools are the same by different business sectors	Cross Tabulation and Chi Square

Table 6.5: Business sector analysis matrix

Duration of LSS use in the workplace (Q10)

The aim from this analysis is to explore if the different business sector types have been using Lean and/or Six Sigma for the same amount of time statistically. As the responses were in the form of a scale non parametric data Kruskal-Wallis tests were performed to conduct this analysis.

The resulting Kruskal-Wallis tests (appendix table C.27) indicate that with a non-significant p-value of 0.623 that the 2 industry sector analysed were the same.

Success of Lean and / or Six Sigma Projects in reaching company goals (Q15)

From examining the level of success achieved from the use of LSS with manufacturing and service sectors using the Kruskal-Wallis test resulted in high p-value of 0.435 (appendix table C.28). This demonstrates that there is no statistical difference present between the 2 industry sector types with a median of 4; therefore they agreed most frequently that they achieved benefits from LSS "most of the time; this is illustrated in Figure 6.5.

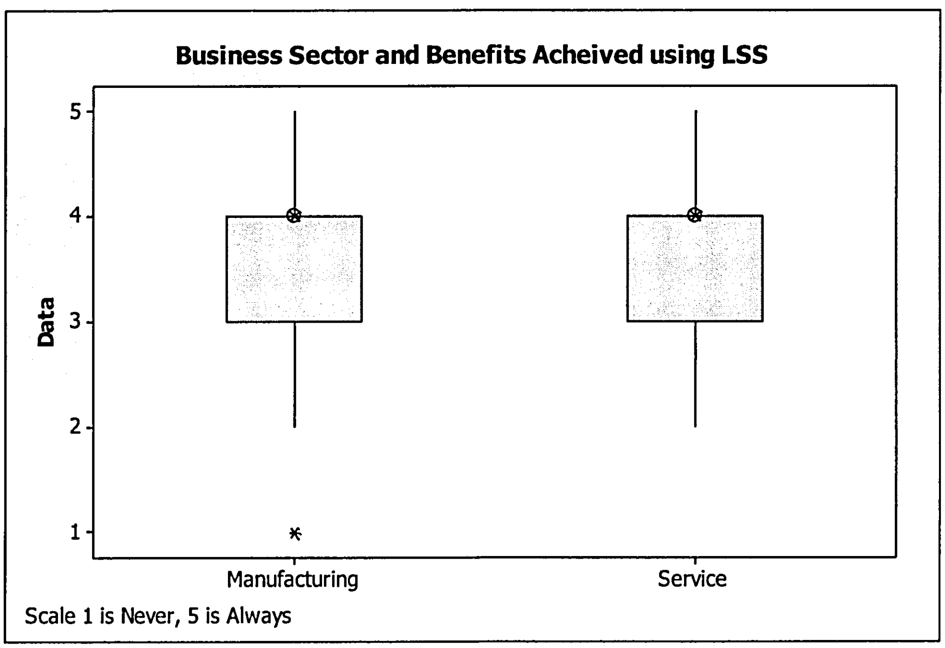


Figure 6.5: Business sector and success of Lean and/or Six Sigma projects

Biggest Concerns over the deployment of LSS in the Organisation (Q16)

The respondents of the 2 industry sector types they were asked if they had the same concerns over the deployment of LSS in their organisation. The top 5 concerns shown in Figure 5.17 are used for this analysis.

The Chi-Square tests (appendix table C.29) demonstrated that concerns of both manufacturing and service sectors the same statistically for 4 of the top 5 concerns however a statistical difference could be found with the history of failed projects where the p-value is rounded up to 0.05.

Examining the analysis results (appendix table C.30) further it can be seen that the results suggest that manufacturing is statistically more concerned about its history of failed LSS projects within its organisations than the service sector organisations.

Environmental Benefits of LSS (Q18)

This analysis examines the 2 different sector types to explore if the environmental benefits of LSS (Q18) were statistically the same. Due to the 5 point rating scale employed (Never to Always) for the response it was necessary to utilise the Kruskal-Wallis technique for this analysis. The study uses a sample of 306 responses out of the total 389 from this survey section. 83 of the respondents from the 2 sector types were not aware whether LSS had achieved environmental benefits and were therefore not part of this analysis.

The analysis results (appendix table C.31) demonstrate that the two sector types do not differ statistically; p-value of 0.662 when the data has been adjusted for ties. The boxplot (Figure 6.6) further demonstrates graphically the similarity of the results.

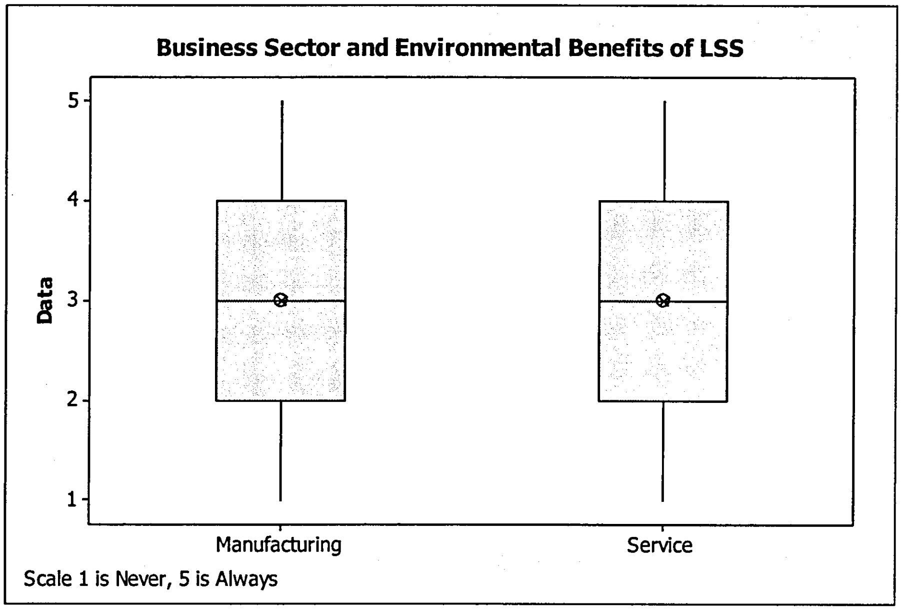


Figure 6.6: Business sector and Environmental benefits of LSS

It can therefore be perceived that the respondents from both industry sectors types most frequently thought that the use of LSS had provided environmental benefits "half the time" from their experience.

Environmental Negatives of LSS (Q20)

By analysing the environmental negatives achieved through the deployment of LSS, the following tests are aimed to deduce if there was a statistical difference between the manufacturing and service sector types. The Kruskal-Wallis tests (appendix table C.32) indicated a non-significant p-value of 0.543 (adjusted for ties) thus it can be stated that the 2 industry sectors types are statistically the same and no additional tests were conducted for this reason.

Knowledge of Green or Environmental Versions of Lean and /or Six Sigma (Q22)

The following series of test compares both the manufacturing and service sectors and the level of awareness that they possess of new "green" or environmental Lean and/or Six Sigma approaches. The cross tabulation and Chi-Square test for "Green Lean" (appendix table C.33) demonstrates that no statistical difference can be found.

However subsequent analysis testing the awareness of Green Sigma (appendix table C.34) yielded a p-value of 0.039. Viewing the tabulated statistics in the table below it can be seen that awareness is low for this approach but knowledge is statistically higher in the service sector in relation to manufacturing.

Similarly for "Green Lean Sigma" the tests (appendix table C.35) demonstrated that manufacturing and service sectors are statistically different in their awareness (p-value 0.016). Again this awareness is higher within the service sector (17.31%) when compared to manufacturing (9.01%).

In terms of awareness of none of the 3 "green" options (appendix table C.36) that were available to the LSS users from the 2 different sectors, manufacturing was statistically less aware (p-value 0.029) of these new environmental approaches compared to service organisations.

Value from combined use of LSS and Environmental Management (Q24)

This particular series of tests (appendix table C.37) aims to determine if the combined use of LSS and environmental management was seen of value by the different business sectors. This involved Chi-square tests being performed on the respondent's data and this question provided the respondents with the option to respond to this question with the usual "no" or "yes" and in addition "not considered this before".

From the Chi-Square test performed on the manufacturing and service sectors a p-value of 0.171 indicated that there were no significant statistical difference between the different sector types.

LSS enhancement of current Environmental Management Practices (Q25)

The following cross tabulation and Chi-Square tests examines if there is a statistical difference between the business sector types and the use of LSS to enhance current environmental management practices. From these tests (appendix table C.38) it can be demonstrated that there is no statistical difference between these results with a p-value of 0.098.

Impact of Increasing Environmental Legislation (Q26)

This Chi-Square test aimed to clarify if LSS users from the manufacturing and service sector types had the same concern statistically over the impact of increasing levels of environmental legislation in their organisation.

The Chi-Square tests (appendix table C.39) resulted in a p-value of 0.033 indicating that the responses from the 2 sector types were statistically different. The LSS respondents from the manufacturing sector were more highly concerned (57.51%) about the impact of environmental legislation when compared to the service sector (45.51%).

Personal concern level over the environment (Q27)

The following cross tabulated tests (appendix table C.40) were conducted on the respondents own personal concerns for the environment by the industry sector. The aim was to determine if they had the same concerns across manufacturing and service sectors. This particular question used a rating scale therefore a Kruskal-Wallis test was performed on the data and the resulting p-value of 0.996 indicated that the 2 structure types did not differ statistically. Refer to Figure 6.7 where both manufacturing and service sectors have a median value of 4.

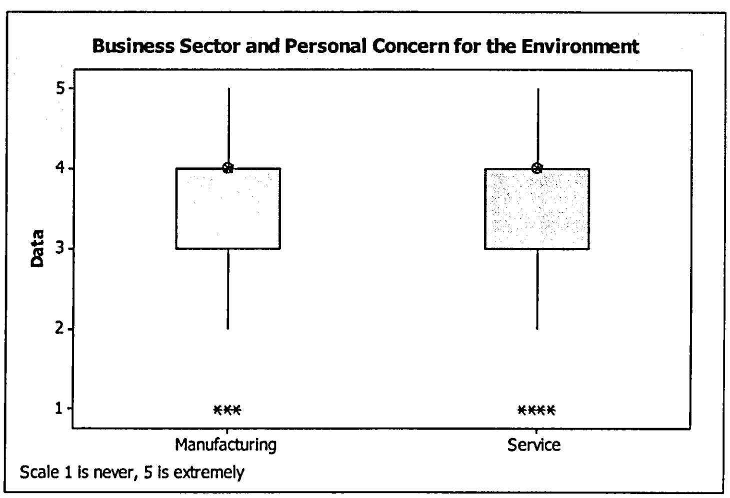


Figure 6.7: Business sector and personal environmental concern levels

Types of Environmental Concern (Q28)

The next set of statistical tests (appendix table C.41) examined the top 5 environmental concerns when cross tabulated with the manufacturing and services sectors. The Chi-Square tests showed that statistically there is no difference between the 2 business sectors, as each test resulted in p-values ranging from 0.481 to 0.873.

Key organisation drivers towards going "Green" (Q29)

Chi-Square tests were performed on the key drivers towards going "green cross tabulated with manufacturing and service business sectors. Of the 5 different driver options, 4 did not differ statistically however there was a difference identified regarding legislation (appendix table C.42) where a p-value of 0.001 was recorded. It can be seen from the tabulated statistics that manufacturing (67.81%) considers legislation to be more of a key organisational driver towards going green than the service sector (50.64%).

LSS and environmental employees working together on Business Improvement Projects (Q31)

From this analysis (appendix table C.43) the aim was to determine if the different business sectors have the same percentage of LSS and environmental employees working together on business process improvement projects in the respondent organisation.

The manufacturing sector responses produced a 40.34% response in comparison to the service sector 33.48% however the cross tabulation and Chi-Square tests revealed that there was no statistical difference between the business sector types with a p-value of 0.444.

Value of developing Green or Environmental Versions of LSS tools and techniques (Q33)

Cross tabulation and Chi-Square tests were performed to determine whether the development of "Green" LSS tools and industry sector types were statistically the same.

Of the top 5 tools and techniques analysed 4 of the tests were proven to be statistically the same. Statistical difference was identified with respect to "Green 5S" (appendix table C.44) with a low value of 0.001 resulting. Responses from the Manufacturing sectors realised 75.54% whilst the service sector perceived the development of "Green 5S" as of less value.

6.5.1 Business Sector Analysis Results Summary

The pertaining results for this section of analysis by business sector are summarized in the Table 6.6.

Business Sector Analysis Results

Q7	Result	P-Value
Q10	Statistically the same	0.623
Q15	Statistically the same	0.435
Q16	Manufacturing Sector statistically different to Service sector, it has a higher history of failed LSS deployments in their organisation	0.052
Q18	Statistically the same	0.662
Q20	Statistically the same	0.543
Q22	Awareness of Green Sigma is statistically different between Manufacturing and Service Sectors. The Service sector is more aware of this approach. Same for Green Lean Six Sigma. Overall knowledge of Green Lean and or Six Sigma Approaches is also statistically different with Service sector having a larger awareness	Green Sigma 0.039 Green Lean Six Sigma 0.016 None of the above 0.029
Q24	Statistically the same	0.171
Q25	Statistically the same	0.098
Q26	Manufacturing Sector statistically different to Service sector, it has a higher concern over the impact of increasing environmental legislation on its organisation	0.033
Q27	Statistically the same	0.996
Q28	Statistically the same for the top 5 answers	0.481 to 0.873
Q29	Legislation - Manufacturing is statistically different to service sector, legislation is a higher driver towards going green. All other drivers statistically the same.	0.001
Q31`	Statistically the same	0.444
Q33	Green 5S - Manufacturing statistically different to service sector, seeing it as of higher value as a tool. All others in the top 5 are the statistically the same	0.001

Table 6.6: Business Sector Analysis Results

6.6 Company Structure Analysis (Q6)

Within this section of the analysis will examine the different organizational structure types (Q6). The aim will be to determine if there are any statistically significant differences between the organizational structure types when cross tabulated to a selection of key questions supplied to the respondents in the survey.

From the results in Figure 5.6 there were responses from 6 different organisational structure types. Of these 4 structure types were chosen as part of the analysis. Responses from franchise and governmental structure types were insufficient to undertake statistical analysis and were removed from the study. Sole trader and partnership structures were combined as their inherent characterises in terms of structure and setup are very similar in principle.

The total sample size for this part of the analysis is 394 out of the 427 used formerly. This included the 33 samples removed for the franchise and governmental sector types as this limited sample would not add any value to this element of analysis. The Table 6.7 below depicts the sample sizes for each of the structure types presented in this section.

Structure Type	Abv	Sample Size (n)
Sole trader and Partnerships	ST/PTS	60
Limited	LTD	133
Public Limited Company	PLC	201
		394

Table 6.7: Structure Type Sample size

The following detailed analysis matrix by organisational structure type is summarized in Table 6.8 which clarifies the key questions cross tabulated using Chi-Square test and also Kruskal-Wallis/Mann-Whitney tests depending on the question type analysed. The Table 6.9 the end of this part of the section summarizes the results of the analysis for quick reference in terms of statistical significant and related p-values.

Company Structure Analysis Matrix			
Q6	Q6 Company Structure - Small, Limited and PLC	Objective	Statistical Technique
Q10	How long have you been using the Lean and/or Six Sigma approaches?	Is the maturity of LSS the same in different Company Structure types	Kruskal Wallace and Mann-Whitney Tests
Q15	Has Lean and or Six Sigma projects been successful in reaching the goals/expectations of your organisation?	To determine if different company structures have the same scale of benefits from deploying LSS	Kruskal Wallace and Mann-Whitney Tests
Q16	What are your the biggest concerns that you have over the deployment of Lean and/or Six Sigma within your organisation?	Do different company structures have the same concerns over the deployment of LSS	Descriptive statistics, Cross Tabulation and Chi Square
Q18	Has the implementation of Lean and/or Six Sigma resulted in any environmental benefits within your organisation?	Do different company structures view the Environmental benefits of LSS to the same level	Kruskal Wallace and Mann-Whitney Tests
Q20	Has the implementation of Lean and/or Six Sigma resulted in any environmental problems within your organisation?	Do different company structures view the Environmental negatives of LSS to the same level	Kruskal Wallace and Mann-Whitney Tests
Q22	Have you heard of Environmental or Green versions of Lean and or Six Sigma, please tick those that apply?	Is the understanding of Green LSS the same in company structures	Descriptive statistics, Cross Tabulation and Chi Square
Q24	Do you consider a combined approach of Environmental Management with Lean and/or Six Sigma of value to your organisation?	Do different company structures view the combined use of Environmental Management and LSS of value in their organisation the same	Descriptive statistics, Cross Tabulation and Chi Square
Q25	Do you think Lean and/or Six Sigma enhances current environmental management practices?	Do different company structures view that LSS enhances current environmental practices the same	Descriptive statistics, Cross Tabulation and Chi Square
Q26	Are you concerned about the impact of increasing environmental legislation and targets on your organisation?	Do different company structures view the impact of increasing environmental legislation the same	Descriptive statistics, Cross Tabulation and Chi Square
Q27	How much are you personally concerned about the environment?	Do different company structures have the same level of personal concern for the environment.	Kruskal Wallace
Q28	In general are your biggest environmental concerns, please tick all that apply?	To determine if the environmental concerns across different company structures are the same	Cross Tabulation and Chi Square
Q29	What is driving your organisation towards becoming "Green", please tick all those that apply?	To identify if the key drivers to go green the same in different company structures	Cross Tabulation and Chi Square
Q31`	Do Lean and/or Six Sigma teams work together with Environmental employees or functions in your organisation on business improvement projects?	Determine if different company structures have the same level of LSS and environmental employees working together on BIP.	Cross Tabulation and Chi Square
Q33	Which of the following tools and techniques do you consider would be of value if developed into Environmental or Green Lean Six Sigma tools and techniques, please tick all that apply?	To determine if the LSS tools deemed to be of value when developed into "Green "LSS Tools are the same by different company structures	Cross Tabulation and Chi Square

Table 6.8: Company Structure analysis matrix

Duration of LSS use in the workplace (Q10)

The objective of this analysis is to deduce if the different organisation structure types have been using Lean and/or Six Sigma for the same amount of time. As the responses were in the form of a scale using non parametric data Kruskal-Wallis tests were performed to conduct this analysis.

The resulting Kruskal-Wallis tests (appendix table C.45) indicate that with a p-value of 0.139 that the 3 structure types did not differ statistically.

As the results gave a higher median for the sole trader and partnership group, additional analysis was performed using an unstacked ANOVA (appendix table C.46). The test was set with a 95% confidence interval and from this test it can be seen that there no significant difference. Therefore it can be concluded that statistically the 3 structure types have been using LSS for the same amount of time.

Success of Lean and / or Six Sigma Projects in reaching company goals (Q15)

The following analysis (appendix table C.47) examining the level of success achieved from the use of LSS with the 3 different organisational structure types using the Kruskal-Wallis test resulted in p-Value of 0.115 therefore demonstrating that there is no statistical difference present. Overall all 3 structure types had a median of 4 therefore the data midpoint centred on that they achieved benefits from LSS "most of the time".

Biggest Concerns over the deployment of LSS in the Organisation (Q16)

LSS users of the 3 structure types were asked if they had the same concerns over the deployment of LSS in their organisation. This analysis focused on the top 5 concerns shown in Figure 5.17 and this analysis used the Chi-Square test function in Minitab.

The analysis conducted highlighted that the concerns by the 3 different LSS role groups over the deployment of LSS did not differ statistically for all the top 5 concerns. The results (appendix table C.48) of the Chi-Square tests demonstrate p-values in excess of 0.05.

Environmental Benefits of LSS (Q18)

For the 3 different structure types this analysis examines if the environmental benefits of LSS (Q18) were statistically the same. The study uses a sample of 313 responses out of the total 394. From the survey 81 of the respondents from the 3 group types were not aware whether LSS had achieved environmental benefits and were therefore not part of this analysis.

From the results of the test (appendix table C.49) a p-value of 0.085 was achieved suggesting that the sample for the 3 different structure types was the same. However as this value was close to the significant value of 0.05 additional analysis was subsequently performed using Mann-Witney tests.

The outcome of this analysis is summarized in appendix table C.50 showing that there is a statistical difference between LTD and PLC organisations. The test indicates that LTD organisation's view the environmental benefits of LSS to be greater than PLC type organisational structures.

Environmental Negatives of LSS (Q20)

Analysing the environmental negatives achieved through the deployment of LSS, the next tests aimed to deduce if there was a statistical difference between the 3 organisational structure types. The result (appendix table C.51) indicated a p-value of 0.135 (adjusted for ties) therefore it can be concluded that the 3 structure types were not significantly different and no additional tests were required.

The boxplot of the results (Figure 6.8) from the Kruskal-Wallis tests also shows graphically the similarity of the responses for this particular question. In terms of the medians, all 3 structure types view that the environmental negatives of LSS are mostly 'never' in their experience.

However it is worth noting that all three samples contain outliers (Anscombe 1960) and these should not be ignored. There can be various reasons for outliers including data entry errors and lack of understanding of the question being asked. However in this instance it is reasonably possible that the respondents have experienced environmental negatives from the deployment of LSS in their business structure types due to the reasons clarified in Section 2.3.3. With this in mind these outliers would be useful points of focus for further research inquiries.

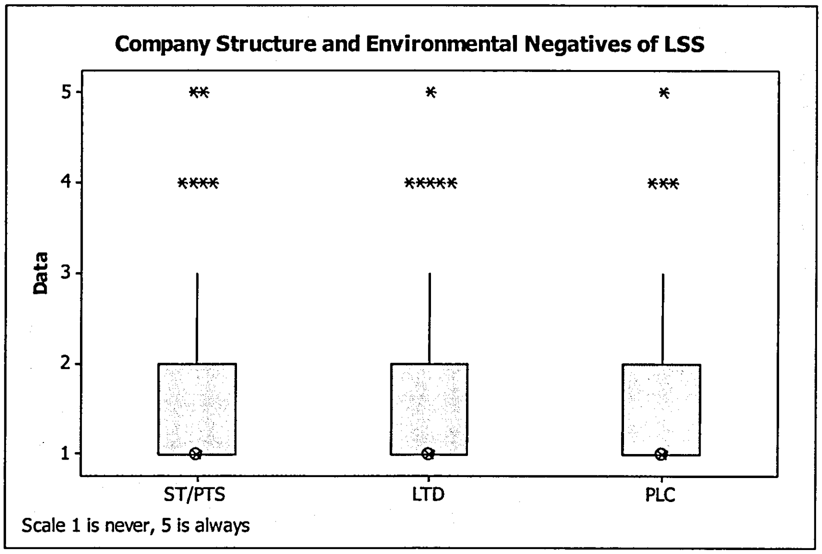


Figure 6.8: Company structure and environmental negatives of LSS

Knowledge of Green or Environmental Versions of Lean and /or Six Sigma (Q22)

This analysis compares the 3 organisation types and the level of awareness of new "green" or environmental Lean and/or Six Sigma approaches. The cross tabulation and Chi-Square tests (appendix table C.52) demonstrate for each of the 3 choices Environmental Lean and/or Six Sigma approaches no statistical difference can be found.

However additional tests (appendix table C.53) which asked the respondents about their knowledge of "none of the options" showed that there was a statistical difference between the 3 organisational structures types with the significant p-value of 0.011. Interestingly the smallest organisation types, sole traders and partnerships have the highest knowledge overall of these new "Green" LSS approaches with 43.44% and the largest organisations namely PLC's have the least knowledge currently with 25.37%.

Value from combined use of LSS and Environmental Management (Q24)

The aim with this particular series of tests was to determine if the combined use of LSS and environmental management was seen of value by the different organisational structure types. This involved Chi-square tests on the respondent's data. This question provided the respondents with the option to respond to this question with the usual “no” or “yes” and in addition “not considered this before”.

From the Chi-Square test (appendix table C.54) performed on the 3 organisational structure types a p-value of 0.116 resulted indicating that that there no statistical difference between the different LSS role type groups indicating agreement about the value of combining LSS and environmental management in their organisations with 48.33% to 61.45% of the respondents being in favour.

LSS enhancement of current Environmental Management Practices (Q25)

In these cross tabulation and Chi-Square tests (appendix table C.55) the statistical difference between the company structure types and the use of LSS to enhance current environmental management practices was analysed. From these tests it can be reported that there is no statistical difference between these results with a p-value of 0.798 and therefore no additional analysis was conducted as there was general agreement between the 3 structure types of the enhancement of environmental management practices through the use of LSS.

Impact of Increasing Environmental Legislation (Q26)

This Chi-Square test aimed to clarify if LSS users from the 3 organisational structures types had the same concern over the impact of increasing levels of environmental legislation in their organisation.

The subsequent tests (appendix table C.56) performed yielded a high p-value of 0.639 indicating that the responses from the different organisational structure type were statistically the same, with general agreement of 51.67% to 54.89% of the structure types that they are concerned over the impact of increasing levels of environmental legislation.

Personal concern level over the environment (Q27)

Regarding their own personal concerns for the environment the respondent's responses were for this analysis cross tabulated by the organisational structure types. The aim was to determine if they had the same concerns across the 3 different structures.

As this question used a rating scale a Kruskal-Wallis test was performed on the data and a non-significant p-value of 0.693 resulted (appendix table C.57) indicating that the 3 structure types were statistically the same. Overall respondents from all 3 structure types most commonly selected that they were highly concerned about the increasing levels of environmental legislation on their organisation.

Types of Environmental Concern (Q28)

The top 5 Environmental concerns shown for each of the 3 structure types are shown in appendix table C.58. Out of these top 5 concerns the only statistical difference found in the Chi-Square tests was for air quality where a p-value of 0.030 resulted.

To summarise (appendix table C.59) the ST/PTS structure grouping indicated a lower concern level (48.33%) than the LTD and PLC type organisations (60.90%-67.16%) for air quality.

Key organisation drivers towards going "Green" (Q29)

The following Chi-Square tests (appendix table C.60) performed on the key drivers towards going "green cross tabulated with the 3 different organisation types clearly demonstrate no statistical difference between the 5 options presented to the respondents with p-values ranging from 0.212-0.614, therefore no additional analysis were warranted.

LSS and environmental employees working together on Business Improvement Projects (Q31)

These tests aimed to determine if the different company structures have the same percentage of LSS and environmental employees working together on business process improvement projects in the respondent organisation. Using cross tabulation and Chi-Square tests (appendix table C.61), it was determined that there was no statistical difference between the different organisational structure types (p-value of 0.617).

Value of developing Green or Environmental Versions of LSS tools and techniques (Q33)

The results of 4 of the tests found no statistical difference (appendix table C.62). However a potential statistical difference was found with the development of a "green" 7 waste tool. This yielded a p-value of 0.077 which was higher than the <0.05 p-value representing statistical difference.

Further analysis of this data (appendix table C.63) demonstrated that a statistical difference did exist between the Sole trader / Partnership structure grouping and LTD organisations. The Chi-Square test resulted in a p-value of 0.024 with the LTD structure respondents viewing 7 Wastes as being of higher value if developed into a green LSS tool. There was no other statistical difference from the other combinations in the cross tabulation tests performed.

6.6.1 Company Structure Analysis Results Summary

The pertaining results for this section of analysis by company structure are summarized in the Table 6.9.

Company Structure Analysis Results		
Q6	Result	P-Value
Q10	Statistically the same	0.139
Q15	Statistically the same	0.115
Q16	Statistically the same	0.065 to 0.812
Q18	LTD is statistically different to PLC but not ST/PLC. LTD is statistically greater in its perceived level of environmental benefits	0.020
Q20	Statistically the same	0.224
Q22	Knowledge of 1,2 and/or 3 was statistically different with ST/PTS having the highest awareness and PLC's the lowest awareness	0.011
Q24	Statistically the same	0.116
Q25	Statistically the same	0.798
Q26	Statistically the same	0.639
Q27	Statistically the same	0.693
Q28	1. General waste - the same, 2. Air Quality - ST/PTS statistically different having a lower concern about air quality, 3. Water quality - the same, 4. Energy production - the same, 5. Animals plants -the same	0.030
Q29	Statistically the same	0.212 to 0.614
Q31`	Statistically the same	0.617
Q33	Statistically the same	0.077 to 0.664

Table 6.9: Company Structure Analysis Results

6.7 LSS Role Type Analysis

This particular section of the analysis examines the different Lean and/or Six Sigma role types (Q11). The aim is to determine if there are any statistically significant differences between the Lean and/or Six Sigma role types when cross tabulated to a selection of the key questions in the survey.

The total sample size for this part of the analysis is 405 out of the 427 used formerly. 22 samples were removed for this part of the study as these respondents specified that they had no LSS role therefore it was assumed that these samples would not provide any value to this element of analysis. Of this sample the different role types were groups in terms of the level of knowledge and training as shown in Table 6.10.

LSS Role	Abv		Level of Knowledge / Training received
Champion	CH		Low
Yellow belt	YB		
Team Member	TM		
Green Belt	GB		Medium
Practitioner	LP		
Black Belt	BB		High
Master Black Belt	MBB		
Trainer	TR		
		Total Sample	

Table 6.10: Role and LSS level of knowledge/ training received

The following detailed analysis matrix by LSS role type is depicted in Table 6.11 which demonstrates the key questions cross tabulated using Chi-Square test and also Kruskal-Wallis/Mann-Whitney tests depending on the question type analysed.

LSS Role Analysis Matrix

Q11	Lean Six Sigma role question	Objective	Statistical Technique
Q10	How long have you been using the Lean and/or Six Sigma approaches?	Is the maturity of LSS the same in different LSS Role Types	Kruskal Wallace and Mann-Whitney Tests
Q15	Has Lean and or Six Sigma projects been successful in reaching the goals/expectations of your organisation?	To determine if different LSS Roles have the same scale of benefits from deploying LSS	Kruskal Wallace and Mann-Whitney Tests
Q16	What are your the biggest concerns that you have over the deployment of Lean and/or Six Sigma within your organisation?	Do different company LSS Roles have the same concerns over the deployment of LSS	Descriptive statistics, Cross Tabulation and Chi Square
Q18	Has the implementation of Lean and/or Six Sigma resulted in any environmental benefits within your organisation?	Do different company LSS Roles view the Environmental benefits of LSS to the same level	Kruskal Wallace and Mann-Whitney Tests
Q20	Has the implementation of Lean and/or Six Sigma resulted in any environmental problems within your organisation?	Do different LSS Roles view the Environmental negatives of LSS to the same level	Kruskal Wallace and Mann-Whitney Tests
Q22	Have you heard of Environmental or Green versions of Lean and or Six Sigma, please tick those that apply?	Is the understanding of Green LSS the same in LSS Roles	Descriptive statistics, Cross Tabulation and Chi Square
Q24	Do you consider a combined approach of Environmental Management with Lean and/or Six Sigma of value to your organisation?	Do different LSS Roles view the combined use of Environmental Management and LSS of value in their organisation the same	Descriptive statistics, Cross Tabulation and Chi Square
Q25	Do you think Lean and/or Six Sigma enhances current environmental management practices?	Do different LSS Roles view that LSS enhances current environmental practices the same	Descriptive statistics, Cross Tabulation and Chi Square
Q26	Are you concerned about the impact of increasing environmental legislation and targets on your organisation?	Do different LSS Roles view the impact of increasing environmental legislation the same	Descriptive statistics, Cross Tabulation and Chi Square
Q27	How much are you personally concerned about the environment?	Do different LSS Roles have the same level of personal concern for the environment.	Kruskal Wallace
Q28	In general are your biggest environmental concerns, please tick all that apply?	To determine if the environmental concerns across different LSS Roles are the same	Cross Tabulation and Chi Square
Q33	Which of the following tools and techniques do you consider would be of value if developed into Environmental or Green Lean Six Sigma tools and techniques, please tick all that apply?	To determine if the LSS tools deemed to be of value when developed into "Green "LSS Tools are the same by different LSS Roles	Cross Tabulation and Chi Square

Table 6.11: LSS role type analysis matrix

Duration of LSS use in the workplace (Q10)

The objective of this analysis is to deduce if the different LSS role types have been using Lean and/or Six Sigma for the same amount of time. As the responses were in the form of a scale using non parametric data Kruskal-Wallis tests were performed to conduct this analysis.

The analysis (appendix table C.64) for the LSS user 3 group types resulted in a low p-value of 0.001 indicating that there was a statistical difference between the 3 groups. In order to clarify where this difference exist it was necessary to drill down and perform Mann-Whitney tests on two groups at a time.

The boxplot below (Figure 6.9) would suggest that those from the BB/MBB/TR group have been using LSS longer than the 2 other groups, however the Mann-Whitney tests were necessary to test this assumption.

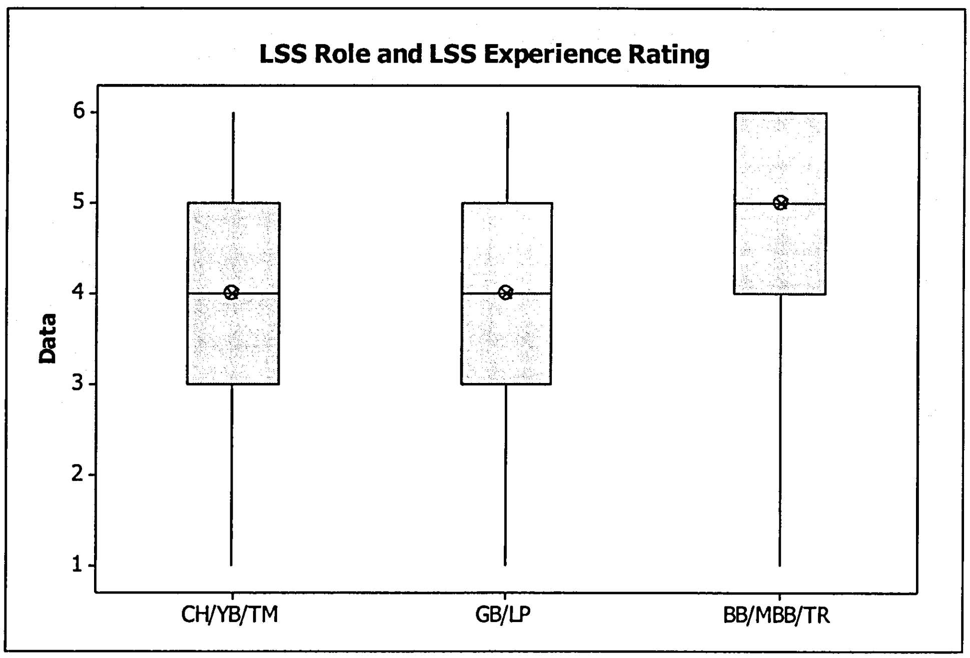


Figure 6.9: LSS role and LSS experience

The Mann-Whitney tests were set with the alternative to "greater than" in reference to the first and second sample. The results of this test are depicted in appendix table C.65.

These results demonstrated that LSS users from the group with the most experience and received training namely Black Belts, Master Black Belts and trainers have been using LSS longer than the other two groups analysed. Whereas the two groups with less experience and knowledge are statistically not different to one another, p value = 0.3180.

Success of Lean and / or Six Sigma Projects in reaching company goals (Q15)

Analysis conducted examining the level of success achieved with the 3 different role groups using the Kruskal-Wallis test resulted in p-value of 0.129 therefore indicating that there is no statistical differences. These results are depicted in the appendix table C.66. See boxplot, (Figure 6.10) all three groups reported a Median of 4 therefore the respondents from each group thought that their Lean and/or Six Sigma projects achieved their goals "most of the time".

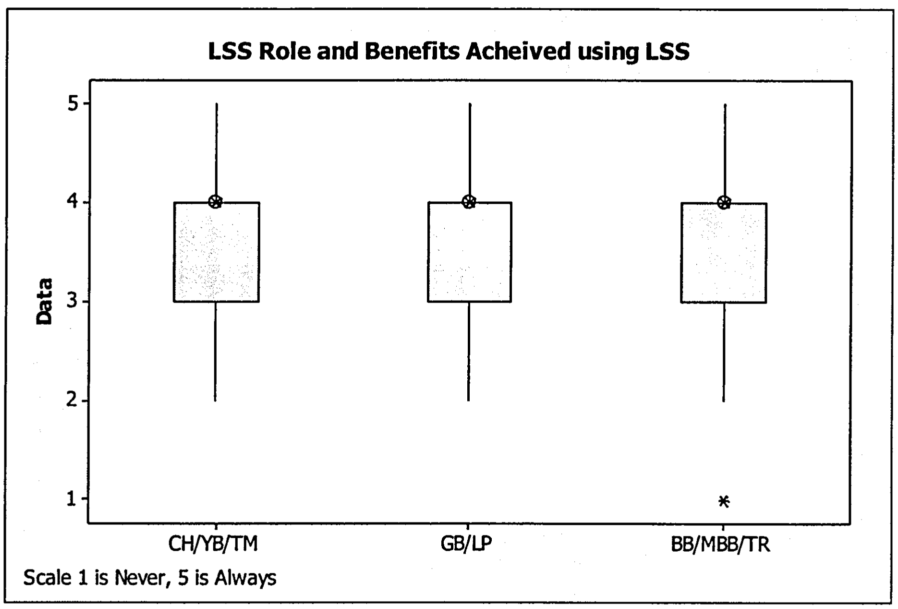


Figure 6.10: LSS role type and LSS Benefits

Biggest Concerns over the deployment of LSS in the Organisation (Q16)

With this analysis the aim was to determine if LSS users of the 3 role type groups had the same concerns over the deployment of LSS in their organisation. This study focuses on the top 5 concerns shown in Figure 5.17.

The results from the analysis (appendix table C.67) showed that the concerns by the 3 different LSS role groups over the deployment of LSS were the same statistically for all the top 5 concerns. The results below of the Chi-Square tests show p-values well in excess of 0.05. This lack of conflict over the concerns of the deployment between the different role types demonstrate a consistency across all the 3 group types, which provide useful information regarding the ELSSSA framework development in section 9.

Environmental Benefits of LSS (Q18)

The analysis for this study uses a sample of 321 responses out of the total 405 as 84 of the respondents from the 3 group types were not aware whether LSS had achieved environmental benefits.

The results from the Kruskal-Wallis test (appendix table C.68) demonstrate that there is no statistical difference between the 3 group types by LSS role with a high p-Value of 0.451. Therefore the level of benefit achieved by the 3 group types was viewed most commonly by the group types as "half the time".

Environmental Negatives of LSS (Q20)

The next tests involved analysing the environmental negatives achieved through the deployment of LSS, to deduce if there was a statistical difference between the 3 groups of LSS role type. The result (appendix table C.69) indicated a p-value of 0.029 (adjusted for ties) indicating that the 3 LSS role groups were statistically different and therefore it was necessary to perform further tests using Mann-Whitney techniques to determine where the difference lies.

These results and boxplot plot in Figure 6.11 suggest that the difference was with the group with the least training and knowledge (CH/YB/TM) who appear to have experience more environmentally negative experiences from deploying LSS with a median of 2 compared to 1 for the other 2 LSS role group types.

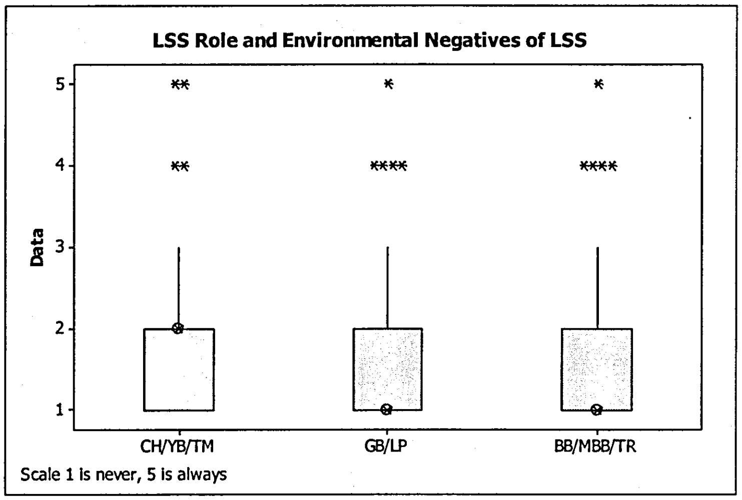


Figure 6.11: LSS Role and environmental negatives from using LSS

This was tested with Mann-Whitney tests (appendix table C.70) which indicated that the group with the least training in LSS (CH/YB/TM) was statistically different to the other 2 group types, but there were no significant differences (p value of 0.4766) between the other groups (GB/LP and BB/MBB/TR) .

Knowledge of Green or Environmental Versions of Lean and /or Six Sigma (Q22)

From the cross tabulation and Chi-Square tests (appendix table C.71) it can be stated that for each of the 3 choices Environmental Lean and/or Six Sigma approaches no statistical difference are found. In addition when asked about their knowledge of none of the options again there was no statistical difference for the 3 different role type groupings.

Value from combined use of LSS and Environmental Management (Q24)

In order to explore if the combined use of LSS and Environmental management (Q24) was seen of value by the different LSS role groups, Chi-square tests were performed on the respondent's data. Respondents had the option to respond to this question with the usual "no" or "yes" and in addition "not considered this before". Chi-Square tests performed on the 3 LSS groups (appendix table C.72) yielded a non-significant p-value of 0.325 indicating that that there no statistical difference between the different LSS role type groups.

LSS enhancement of current Environmental Management Practices (Q25)

The focus of this analysis was on whether there is a statistical difference between the LSS role type groupings and the use of LSS to enhance current environmental management practices in the LSS user's organisation. From the cross tabulation and Chi-Square tests (appendix table C.73) it can be seen that there is no statistical difference between these results.

Impact of Increasing Environmental Legislation (Q26)

This Chi-Square test aimed to determine if the LSS users from the 3 different role groupings had the same concern over the impact of increasing levels of environmental legislation in their organisation.

The results of the tests performed showed a p-value of 0.002 (appendix table C.74) therefore indicating that the responses from the different LSS role groups were in fact statistically different.

Viewing the tabulated statistics it was not clear whether all 3 grouping were in fact statistically different from each other. The percentages in the table would suggest this however further analysis was performed in Minitab on 2 samples at a time using Chi-Square to try to prove this statistically. The resulting tests indicated that all 3 grouping were statistically different from one another with p-values ranging from 0.007-0.022. In conclusion the group with the least knowledge and training of LSS have the greatest concern over increasing environmental legislation on their organisation.

Personal concern level over the environment (Q27)

The respondent's answers on regarding their own personal concerns for the environment were for this analysis cross tabulated by the LSS role group types. The aim therefore to determine if they had the same concerns across the different group types. As this question used a rating scale a Kruskal-Wallis test was performed on the data, this is shown in the appendix table C.75

The analysis provided a non-significant p-value of 0.532 when adjusted for ties indicating no significant difference (see Figure 6.12).

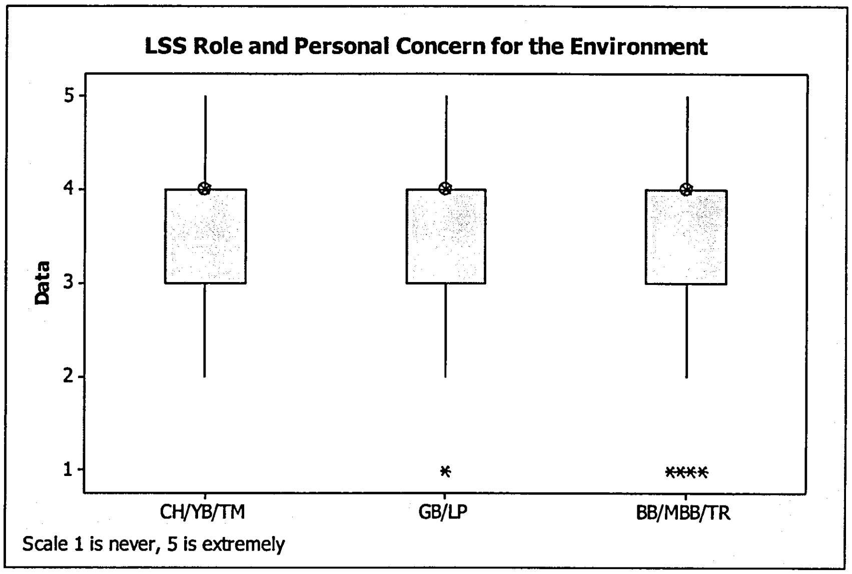


Figure 6.12: LSS role and personal concern over the environment

Types of Environmental Concern (Q28)

From the top 5 Environmental concerns depicted in the summarized appendix table C.76, the Chi-Square tests indicated that statistically there is no difference between the 3 LSS role groupings. Therefore no additional analysis was performed on this data.

Value of developing Green or Environmental Versions of LSS tools and techniques (Q33)

The aim of this analysis was to explore whether the development of "Green" LSS tools and techniques across the 3 LSS role types. The resulting cross tabulation of the respondent's answers and Chi-Square tests indicated that the LSS role type groupings were not statistically different (appendix table C.77).

Therefore it can be summarised that for the top 5 "Green" LSS tools and techniques, the 3 LSS role groups concur with one another on which are of most value.

6.7.1 LSS Role Analysis Results Summary

The pertaining results for this section of analysis by LSS role are summarized in the Table 6.12 below: -

LSS Role Analysis Results		
Q11	Result	P-Value
Q10	BB/MBB/TR have statistically been using LSS longer than the other two role categories	0.000
Q15	Statistically the same	0.129
Q16	Statistically the same	0.138 to 0.709
Q18	Statistically the same	0.451
Q20	YB/CH/TM view the environmental negative consequences of LSS as statistically higher than BB/MBB/TR LSS role types	0.029
Q22	Statistically the same for all 4 options	0.244 to 0.739
Q24	Statistically the same	0.325
Q25	Statistically the same	0.653
Q26	3 role types are statistically different from each other. Secondary analysis shows that YB/TM/CH are the most concerned about the impact of increasing environmental legislation, whilst for GB/LP this was something they had not considered before	0.002
Q27	Statistically the same	0.532
Q28	Statistically the same	0.342 to 0.930
Q33	Statistically the same	0.113 to 0.995

Table 6.12: LSS Role Analysis Results

6.8 Duration of LSS Experience Analysis

This section of the analysis focuses on the duration that the LSS respondents have using Lean and/or Six Sigma (Q10). The aim is to determine if there are any statistically significant differences that occur due to different time levels of LSS when cross tabulated to a selection of key survey questions.

The total sample size analysed in this part of the analysis is 427 respondents. Of this sample the duration of LSS use was set into 4 duration ranges which are depicted in Table 6.13 below:

Experience Years	Qty (n)
0-2	101
2-5	125
5-10	90
10+	111
Sum	427

Table 6.13: LSS experience (years)

The following detailed analysis method by LSS experience is summarized in Table 6.14 which depicts the key questions cross tabulated using Chi-Square test and also Kruskal-Wallis/Mann-Whitney tests depending on the question type analysed.

LSS Experience Analysis Matrix			
Q10	Lean Six Sigma Experience	Objective	Statistical Technique
Q15	Has Lean and or Six Sigma projects been successful in reaching the goals/expectations of your organisation?	To determine if users with different levels of LSS experience have the same scale of benefits from deploying LSS	Kruskal Wallace and Mann-Whitney Tests
Q16	What are your the biggest concerns that you have over the deployment of Lean and/or Six Sigma within your organisation?	Do users with different levels of LSS experience have the same concerns over the deployment of LSS	Descriptive statistics, Cross Tabulation and Chi Square
Q18	Has the implementation of Lean and/or Six Sigma resulted in any environmental benefits within your organisation?	Do users with different levels of LSS experience view the Environmental benefits of LSS to the same level	Kruskal Wallace and Mann-Whitney Tests
Q20	Has the implementation of Lean and/or Six Sigma resulted in any environmental problems within your organisation?	Do users with different levels of LSS experience view the Environmental negatives of LSS to the same level	Kruskal Wallace and Mann-Whitney Tests
Q22	Have you heard of Environmental or Green versions of Lean and or Six Sigma, please tick those that apply?	Is the understanding of Green LSS the same for users of different levels of LSS experience	Descriptive statistics, Cross Tabulation and Chi Square
Q24	Do you consider a combined approach of Environmental Management with Lean and/or Six Sigma of value to your organisation?	Do users with different levels of LSS experience view the combined use of Environmental Management and LSS of value in their organisation the same	Descriptive statistics, Cross Tabulation and Chi Square
Q25	Do you think Lean and/or Six Sigma enhances current environmental management practices?	Do users with different levels of LSS experience view that LSS enhances current environmental practices the same	Descriptive statistics, Cross Tabulation and Chi Square
Q26	Are you concerned about the impact of increasing environmental legislation and targets on your organisation?	Do users with different levels of LSS experience view the impact of increasing environmental legislation the same	Descriptive statistics, Cross Tabulation and Chi Square
Q33	Which of the following tools and techniques do you consider would be of value if developed into Environmental or Green Lean Six Sigma tools and techniques, please tick all that apply?	To determine if the LSS tools deemed to be of value when developed into "Green "LSS Tools are the same for users of different levels of LSS experience	Cross Tabulation and Chi Square

Table 6.14: LSS experience analysis matrix

Success of Lean and / or Six Sigma Projects in reaching company goals (Q15)

Initial analysis conducted using the Kruskal-Wallis test (appendix table C.78) gave a significant p-value of 0.001 highlighting that a statistical difference was present in the different durations of LSS experience of the respondents.

Secondary analysis was subsequently conducted to determine where the difference exists. Using Mann-Whitney it was possible to deduce that the difference existed between the 5-10 years' experience range and the other 3 experience ranges. Due to the similarity in variance exhibited with the standard deviation a further test was conducted to add confirmation of the statistical difference between LSS users of 5-10 years and the other experience durations. A 1 way unstacked ANOVA test (appendix table C.79) indicates a significant difference in the mean between the users of 5-10 years and the other samples.

Therefore from this analysis it can be summarized that LSS users of 5-10 years' experience report that on average they have experienced a higher degree of success in reaching their goals.

Biggest Concerns over the deployment of LSS in the Organisation (Q16)

The aim is to determine if LSS users of different levels of experience from using the approach have the same concerns over the deployment of LSS in their organisation. Of the 15 different concern types this analysis focuses on the top 5 concerns shown in Figure 5.17. Using the Chi-Square test (appendix table C.80) showed that the concerns over the deployment of LSS did not differ statistically except for the team's knowledge of LSS. This analysis produced a p-value of 0.002.

From the appendix table C.80 it can be seen that LSS users with between 0-2 years' experience have a much higher concern (48.98%) over the internal knowledge that their teams of the LSS approach in comparison to the other 3 experience groups (18.84-28.57%).

Environmental Benefits of LSS (Q18)

The purpose of this analysis was to deduce whether the environmental benefits of LSS (Q18) were the same for LSS users of different ranges of LSS experience. The analysis for this study uses a sample of 335 responses out of the total 427 as 92 of the respondents were not aware whether LSS had achieved environmental benefits.

From the Kruskal-Wallis test a p-value of 0.036 (appendix table C.81) shows that there is a statistical difference between the 4 levels of LSS experience.

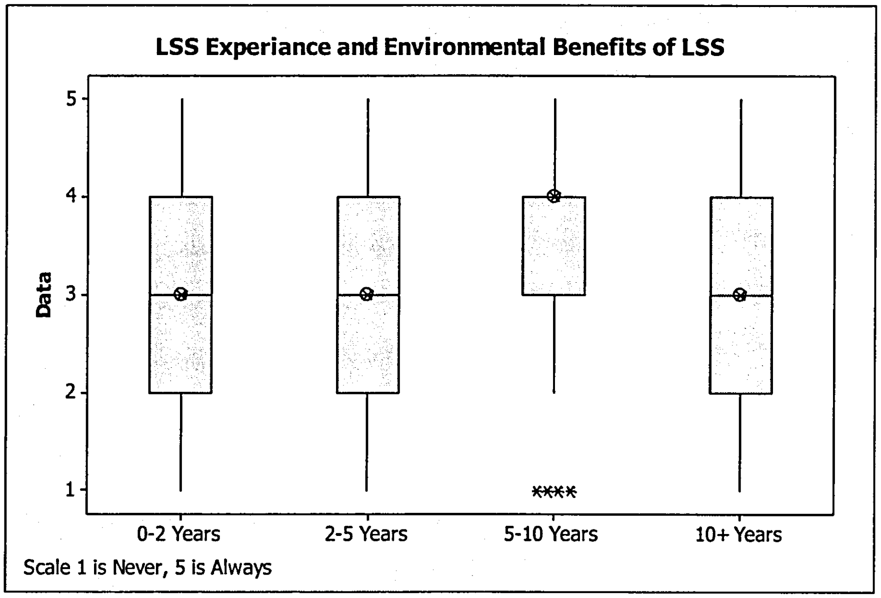


Figure 6.13: LSS Experience and Environmental Benefits of LSS

Further analysis using Mann-Whitney tests indicated that the statistical difference was with the LSS users of 5-10 years range (appendix table C.82) and Figure 6.13. Therefore from this analysis it can be suggested that LSS users of 5-10 years' experience the data midpoint is centred on that they have "mostly achieved environmental benefits" from the deployment of LSS whilst users of the other 3 experience groups data midpoint is centred on that they have achieved environmental benefits "half the time".

Environmental Negatives of LSS (Q20)

The above analysis was repeated for the environmental negatives achieved through the deployment of LSS to identify if there was a statistical difference between the 4 levels of LSS experience. The result indicated with a p-value of 0.231 (appendix table C.83) that the 4 LSS experience groups were did not differ statistically and that so further analysis by Mann-Whitney is unwarranted.

The table also showed a median for all experience groups of 1 meaning that midpoint of the responses is centred on LSS users "never" experienced environmental negatives from their LSS deployments. However this is a perception and a considerable percentage of the respondents asked (30%) did not know if the deployment of LSS had resulted in negative environmental consequences (see boxplot in Figure 6.14).

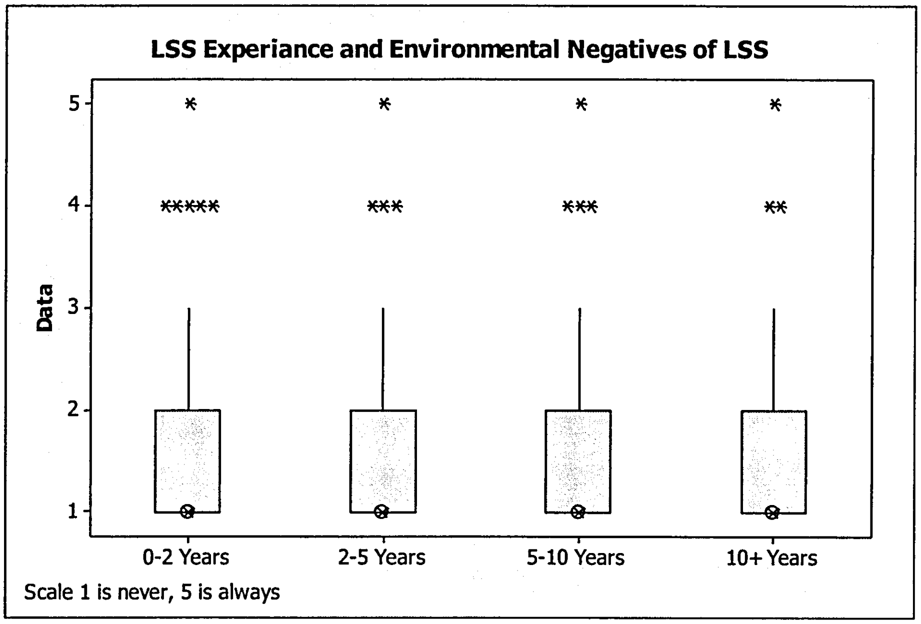


Figure 6.14: LSS experience and environmental negatives from using LSS

Knowledge of Green or Environmental Versions of Lean and /or Six Sigma (Q22)

The aim of this analysis was to test whether users of different levels of LSS experience have the same awareness of new "green" or environmental Lean and/or Six Sigma approaches (Q22). Cross tabulation and Chi-Square test were performed for each of these options to test if they were different. Tests for awareness of Green Lean within the LSS community provide a p-value of 0.005 (appendix table C.84) indicating that there is a statistical difference between the different experience levels of LSS. Reviewing the table produced in Minitab would suggest that LSS users of 5-10 years' experience have a higher awareness of "Green Lean" with 34.44% having heard of the approach. This compares to between 15.20-21.62% for the other 3 experience levels.

Knowledge of "Green Sigma" proved to be statistically the same for all 4 LSS experience groups with a p-value of 0.561 with overall average knowledge being much lower than "Green Lean" (7.26% compared to 21.55%).

Analysis of the data received on awareness of "Green Lean Six Sigma" showed that the 4 groups were not statistically the same with a p-value of 0.002 reported (appendix table C.85). Viewing the responses it could be suggested that the difference in awareness lies with the 0-2 years LSS experience where only 4.95% of respondents had heard of "Green Lean Six Sigma". This compares to 12.00-23.33% for the other experience groups where experience is noticeably higher.

Chi Square Tests for awareness of none of the "new" environmental versions of Lean and/or Six Sigma (appendix table C.86) indicated a p-value of 0.002 showing that the results for the different experience levels are not statistically the same. Viewing the results LSS users of 0-2 years of experience had the lowest awareness of "green" versions of Lean and/or Six Sigma which would appear to make logical sense as they have the least experience of LSS and are new to the community. Users with 5-10 years' experience would appear to have the highest awareness of these new "green" approaches in comparison to the other experience groups with 48.99% having heard of at least 1 of the 3 options. This is considerably higher than users of 10+ years having with 33.33% having heard of these new approaches.

Value from combined use of LSS and Environmental Management (Q24)

This analysis is aimed to deduce if the combined use of LSS and environmental management (Q24) was seen of value by the different LSS experience groupings. Respondents could respond to this question with the usual "no" or "yes" and in addition "not considered this before".

The resulting Chi-Square test performed (appendix table C.87) provided a p-value of 0.253 indicating that there were no statistical difference between the different experience groups. The results show that in percentage terms users of 5-10 years thought that the combined approach was of value the most with 66.22%. In terms of those groups which had not considered the combined approach before LSS users of 0-2 years and 2-5 years were the highest with 38% for each group response.

LSS enhancement of current Environmental Management Practices (Q25)

This Chi-Square analysis (appendix table C.88) focuses on whether there is a statistical difference between the LSS experience groups and the use of LSS to enhance current environmental management practices in the LSS user's organisation. The resulting analysis provides a p-value of 0.078 therefore they are statistically the same across the 4 groups.

In terms of the responses from LSS users that LSS enhances current environmental practices the group with 5-10 years' experience achieved the highest percentage with 73.33%, whilst users of 10+ years were next up at 64.86%. Users with the least experience of LSS responded with the lowest percentage of 52.48%

Impact of Increasing Environmental Legislation (Q26)

The purpose of this Chi-Square test was to determine if the LSS users from the different experience groupings had the same concern over the impact of increasing levels of environmental legislation in their organisation.

The resulting tests (appendix table C.89) provided a p-value of 0.001 therefore indicating that the responses from the different experience groups were statistically different. Viewing the results from the tabulated statistics it can be seen that the LSS users from the 0-2 years had the highest concern (65.35%) over the increasing levels of environmental legislation and the impact on their organisation.

Value of Green/Environmental LSS tools and techniques (Q33)

Cross tabulation and Chi-Square tests were performed on each of the top 5 tools selected. Both Green 7 Wastes and Green 5S had high p-values of 0.394 and 0.160 respectively and would therefore both be viewed as being statistically the same when cross tabulated with the different experience groups.

The same could be said of Green VSM which also did not differ statistically (appendix table C.90) with a p-value of 0.075.

Analysis conducted on the value of developing Green Kaizen (appendix table C.91) resulting in a p-value of 0.014 indicating that there were statistical difference in the responses from the different LSS groups. The percentages from the tabulated statistics highlight that the users with 0-2 years' experience value the development of this tool (43.56%) less than the more experienced users (57.60%-65.56%). Therefore it could therefore be suggested that users with more experience and knowledge of Kaizen view the development of this tool as of higher value than less experienced users from the 0-2 year group.

The final tool analysed using cross tabulation and Chi-Square tests was Green Process Mapping (appendix table C.92) which resulted in a p-value of 0.013 indicating that there was a statistical difference between the 4 experience groupings. As with the previous analysis it can be viewed from the tabulated statistics that the users with the least LSS experience saw this tool development as being of the lowest value out of the 4 groups. Just 44.45% of LSS users from the 0-2 year's group saw the value in developing this tool compared to between 56% to 66.67 for the more experienced groups.

6.8.1 LSS Experience Analysis Results Summary

The results for this section of analysis by LSS experience are summarized in the Table 6.15 below: -

LSS Experience Analysis Results		
Q10	Result	P-Value
Q15	LSS users with 5-10 years experience were statistically different in their response to the other 3 categories. They were more consistent in their response with less variance.	0.000
Q16	All statistically the same except concern over knowledge of the LSS approach. LSS users with 0-2 years experience more highly concerned over the knowledge of the approach than the other 3 categories	0.002
Q18	LSS users with 5-10 years experience were statistically different in their response to the other 3 categories. They level of environmental benefits achieved were greater than the other 3 categories	0.036
Q20	Statistically the same	0.231
Q22	1. Green Lean -LSS users with 5-10 years experience were statistically different to the other 3 categories. They had a higher level of awareness of Green Lean 2. Green Sigma - Statistically the same, 3. Green Lean Six Sigma - Knowledge is statistically lower for LSS users of 0-2 years experience, 4 None of the above - Statistically different, LSS users with 0-2 years experience have the lowest awareness of Green versions of LSS, LSS users with 5-10 years experience have the highest awareness of Green versions of LSS.	Green Lean 0.005 Green Lean Six Sigma 0.002 None of the approaches 0.002
Q24	Statistically the same	0.253
Q25	Statistically the same	0.078
Q26	LSS users with the least experience (0-2 Years) were statistically different to the other 3 categories, they had a higher concern about the increasing environmental legislation on their company	0.001
Q33	Green Kaizen is statistically view of as less value by LSS users with 0-2 years experience. Green process mapping is also statistically different and viewed of as less than the other more experienced age groups	Green Kaizen 0.014 Green Process Mapping 0.013

Table 6.15: LSS Experience Analysis Results

7 Discussion of Results and Analysis

This discussion section will explore and discuss the key findings from the global LSS survey and the resulting statistical analysis. Its objective will be to clarify the main findings in terms of the overall survey results and cross tabulated statistical tests of the 5 main factors analysed. These subsequent findings will be used as a basis for the development of the ELSSSA tools and Framework.

7.1 General Results

The 1st section of the discussion focuses on the general results as depicted in Section 5.

7.1.1 Background Responses

LSS is a male dominated approach as can be witnessed from the survey responses in Figure 5.1 with 81% of the responses from males and just 19% from females. However it is possible that this amount has increased in recent years, the researcher has seen a steady increase in females both attending training courses and conducting projects both in Europe and Asia over the last 5 years. However as industry in general is very much male dominated these figures are not surprising, especially when we examine later questions and we see that manufacturing still dominates and this is of course more male orientated at present. However the increasing usage of LSS in the service sector may see more females become involved in LSS.

The survey gained a well-balanced response from different age groups (Figure 5.2) and also in terms of length of company service (Figure 5.3). At organisational level (Figure 5.4) the LSS users tended to be more management orientated with just 9% claiming to be operational employees and 10% support staff. This could be due to these types of employees not having the kind of access to the internet in relation to management and supervisory staff in their business which is often the case. Also these employees may be less aware of the LSS forums that are available to them generally.

7.1.2 Organisational Profile Responses

The use of LSS globally is very mature in particular in Europe, Asia and the USA. However from the low quantity of responses of certain major global locations such as Africa and Oceania (Figure 5.5) it could be that awareness of the LSS approach may still be low in these locations and this could be resulting in low levels of deployment in these locations at present.

In terms of company structure types (Figure 5.6) that are using LSS, PLC type organisations supplied 46% of the overall responses and LTD companies 32%. These two company types represent the clear majority as company structure types using LSS. This could be due to a number of reasons including the investment required in the training of employees which can be significant for small businesses who do not have large budgets for training. Small businesses may also be less aware of LSS; from the researcher's experience larger businesses appear to have a general understanding of LSS whereas many small businesses are insulated from innovative business improvement methods.

Also LSS is a team approach and very small organisations such as sole traders and partnerships may find that the team approach does not work as effectively for their organisation. Possible exceptions are sole traders and partnerships that are consultant businesses that may be supplying LSS to other organisations.

Viewing the industry sector types using LSS (Figure 5.7) manufacturing is still the most popular industry sector using LSS but the service sector does appear to be growing in its adoption of the approach. There is a wide diversity of service sectors now using LSS with healthcare and banking being the most popular but unusual service sectors such as agriculture, law and even entertainment are starting to use the approach even though in very limited numbers thus far.

Quality (38.1%) and Production (14.6%) are still the dominant functions using LSS in their businesses; however it is encouraging to see the wide of other functions now involved in the deployment of LSS. A significant 10.4% of managers are now using LSS which may go some way to help counter the concerns of management commitment towards LSS that is evident in Figure 5.17.

7.1.3 Lean Six Sigma Responses

Interestingly the majority of the survey respondents (Figure 5.9) had received training in both Lean and Six Sigma (53%), which is a change from 10 years ago (Pepper and Spedding 2010) when the author found that it was more likely that people will be either Lean or Six Sigma trained within their businesses. Of the LSS user population sample, 11% had not received any formal training in Lean and/or Six Sigma. It could be assumed that these LSS users are self-taught possibly via textbooks or internet websites and forums.

In terms of how long LSS users (Figure 5.10) have being deploying LSS it would appear that its growth rate has steadily increased over the years and does not appear to be at the end of its life-cycle as an approach. 21% of users are shown to have 0-2 years' experience of the approach, this compares to 28% having 2-5 years' experience, 25% having 5-10 years' experience and 20% having over 10 years' experience. From judging these figures it looks likely that LSS will continue to remain popular for many years to come.

The roles of LSS users (Figure 5.11) vary considerably however the most popular role type from these responses was "Black Belt" with 24%. This compares to just 11% "Green Belts" which is not in line with the LSS approach where it is recommended that Black Belts manage Green Belts on a ratio between 1:3 to 1:10. These results suggest that there may be too many managers and not enough operational employees for LSS deployments in our organisations. From the author's perspective some large PLC's follow this ratio guide but many businesses that do not have a structured training plan and may train too many people to be Black Belts in their organisations.

An encouraging sign is that 13% of respondents classed themselves as champions, which is a crucial element in order to gain the necessary stakeholder commitment for LSS projects. Less encouraging is that only 1% of the respondents claimed to be yellow belts in their organisations. Yellow belts can provide value added support and commitment to LSS projects as well as conducting their own mini improvement projects so it is disappointing to see such a low percentage of the population in this role.

The type of LSS tools used by the global LSS community (Figure 5.12) yielded few surprise with 5S, fishbone diagrams and process mapping in the top 3. What can be seen though is that the top results are dominated by "Lean" focused tools and techniques with 8 out of the top 10. Use of Six Sigma tools and techniques come much further down the order and it would appear that methods such as

ANOVA, SPC and control charting and the use of statistical software are less used; due to their inherent complexity

LSS users overall were very positive about the benefits (Figure 5.13) achieved from deploying LSS in their businesses. 85.59% reported benefits in terms of improved quality and 80.27% had reduced costs. Also quite crucial was the 65.41% who reported improvement the culture in their businesses.

This is backed up by responses towards LSS reaching its goals (Figure 5.16) with 67% reporting that it "mostly" or "always" did. Only 5% reported rarely and 0% reported never however it must be taken into account that only 9% of the survey respondents were operational employees and therefore these results could be misleading as a balanced perspective across organisational functions may not be presented.

Concerns over the deployment of LSS in their organisation (Figure 5.17) clarified that the biggest concern was management commitment at 69%. The researcher's own experience concurs with this finding where commitment from the bottom is often high but lacking further up the corporate ladder. Also of significance is that 52.8% were highly concerned about the long term sustainability of the approach which backs up theories by Mehta (2004).

Third in terms of concerns were not having the right stakeholders involved. This commonly occurs where Black or Green Belts don't follow the DMAICT approach properly and involve the stakeholders throughout the project and include them in critical meetings and reviews.

Many organisations have many bites at the cherry at LSS and this is identified in the 4th biggest concern of history of failed projects. Many organisations try LSS and fail usually due to not following the approach and usually jumping into the analysis when they should be concentrating on completing the define phase and the project charter in particular.

Fifth on the list of highest concerns is the understanding that of the teams has of LSS. Many businesses and individuals embark on LSS projects without having a proper understanding of the approach. This is sometimes due to lack of training as shown in Figure 5.9 and it can also be down to poor quality training being supplier to them by training providers.

An interesting point to note is that only 4.2% of the respondents thought that LSS was not applicable within their business sector. There had definitely being a sea change relating to this question and if it had been asked 10 years ago the response would have been much higher. The author had this response frequently 10-15 years ago when applying Lean to businesses such as aerospace, food and textiles where the response back then would typically be "it only works in the automotive industry" From this research it can be concluded is this type of response is less likely todays organisations.

7.1.4 Environmental Responses

From an environmental perspective 54% of the respondents reported environmental benefits (Figure 5.18) from using LSS between 50% and 100% of the time. These figures indicate that LSS does possess an excellent way to garner additional environmental benefits in addition to the traditional QCD. Also 22% did not know if they were achieving benefits or not and had not thought about this before.

In terms of the types of environmental benefits achieved from using LSS (Figure 5.19), these were incredibly wide ranging. The largest perceived benefit was reduced energy consumption at 20%. By using less raw materials and producing less scrap, reduced levels of energy are being used by organisations deploying LSS, many companies however may not be aware of this fact.

13% reported less environmental emissions resulting from their projects and this can also be linked to less raw materials being used and reduced scrap levels. Also 10% of the environmental benefits were reported to be reduced usage of hazardous chemicals and 7% less landfill which is linked to fewer defects and rework levels.

Examining the responses toward the environmental negatives of LSS deployments (Figure 5.20) 61% thought that this rarely or never happened whilst a significant 30% were not sure. This is probably because LSS is not often thought of in environmental terms in its conventional approach. Only 4%

reported that LSS resulted in environmental negatives "mostly" or "always" in their business but this could be higher if the "not sure" were clarified further.

Awareness of "Green" versions of Lean and/or Six Sigma (Figure 5.21) are still in their infancy it would appear with "Green Lean" being the most widely heard of by the Global LSS community at 20.84%. This compares to just 7.54% having heard of "Green Sigma" and 12.4% for "Green Lean Six Sigma" Examining these figures could potentially imply that Lean and Green have better synergy than Six Sigma and Green or it could potentially be that it's easier to adapt as an approach as Lean is more simple and easy to understand.

The global LSS community were very positive to the combination of Lean and/or Six Sigma with environmental management (Figure 5.22) in their organisation with 54% in agreement. Just 13% did not see the value in this and a significant 33% had not considered this in their organisation. In addition to this 62% felt that Lean would enhance current environmental management practices (Figure 5.23). This compares to just 8% who did not agree and 30% had not considered this before.

Both of these question responses add credence to the combination of Lean and/or Six Sigma and environmental management and clearly demonstrate how LSS users consider the environmental benefits that can be achieved.

Generally the majority of the respondents were concerned (53%) about the increasing levels of environmental legislation (Figure 5.24) was having on their organisation. From a personal perspective however this concern is higher with 66% (Figure 5.25) of respondents being concerned about the environment either highly or extremely. Their specific personal concerns (Figure 5.26) were focused mostly on general waste from landfill and sea (62.75%), air quality (62.08) and water quality (61.2%).

The largest key driver towards "going green" for their companies (Figure 5.27) was legislation closely followed by customers. As LSS is very much a customer focused approach this is one area where LSS could help environmental management practices.

In terms of the current state on whether LSS employees work with environmental employees (Figure 5.28) on business improvement projects 38% reported that they did so which implies that the DMAIC approach is being applied by some organisations and involving all key stakeholders. However 34% reported that they did not which implies the opposite and 28% were not sure if they did or not.

High demand was demonstrated for environmental or green versions of classic versions of LSS tools and techniques (Figure 5.29) where the respondents viewed 7 wastes (79%), 5S, (68%) and VSM (57%) of value. As clarified earlier the demand is more focused towards Lean tools and techniques rather than Six Sigma and this correlates to the finding discussed earlier regarding awareness of "Green Lean" and "Green Sigma"

7.2 Statistical Analysis

The 2nd part of this section discusses the outcomes of the statistical analysis in Section 6 providing insights into the key differences over the 5 main factors cross tabulated and analysed.

7.2.1 Geographic Location Analysis

From the extensive analysis conducted there were a considerable number of important statistical differences clarified between the 3 global locations analysed. It was found that in terms of LSS users Asia and Europe was fairly evenly balanced between manufacturing and service sectors whist the USA was more focused towards the manufacturing sector. This is an interesting finding as the author has witnessed a steady increase in demand for LSS in the service sectors within Europe and Asia in recent years. There has also been a flurry of journal publications and books relating to LSS and service implementation but the reason why we haven't seen the same increase in the USA is unclear at present.

In terms of the deployment of LSS it was found that the Asia LSS community had been using the approach for less time than both the USA and Europe. As the LSS approach originated in the USA before flowing through to Europe just over 12 years ago (Section 2.2.3), this discovery is probably unsurprising. Asia also reported that they considered that they were more likely to have negative environmental consequences from the use of LSS but no difference was found between the global locations and the environmental benefits from this study.

Additionally Asia's LSS community were more concerned about the environment from a personal perspective. They did however have less concern about general wastes such as landfill than the USA and Europe. This compares to Europe who were less concerned about both air and water quality than Asia and the USA. The reasons for this are well documented in Asia with countries like China suffering with high smog levels on a frequent basis (Mickley 2007). Asia also has less consistent levels of water quality than Europe but it is surprising to see a developed country such as the USA being as concerned as Asia over water quality.

An important finding was that Europe is more highly concerned than both Asia and the USA about the increasing levels of legislation as a driver towards going "green" within their organisation. Europe is seen as a leader in terms of driving forward environmental legislation and it's possible that European businesses are feeling the pressure from this. As discussed in Section 2.5.3 the USA has continued to block climate change treaties and so have major players from Asia such as China so it may be possible that businesses are less concerned over increasing levels of legislation as they are less strict than in Europe.

In terms of the most suitable LSS tools that they considered should be developed into environmental versions there was general consensus for the top 5 tools between the 3 global locations however Asia viewed the required for "Green" VSM as a lesser requirement when compared statistically to both Europe and the USA.

7.2.2 Business Sector Analysis

There were a number of key areas where the analysis of the two main business sectors namely manufacturing and service were statistically different as a result of the analysis. In terms of history of failed LSS projects, manufacturing had experienced more than service sectors. A possible reason for this could be related to the differences between internal structures and cultures of manufacturing organisations compared to service organisations. Service businesses tend to be better equipped at the "softer issues" and many LSS projects fail on due to poor communication and stakeholder management rather than the hard-core use of the tools and techniques.

Regarding awareness of new "Green" Lean and or Six Sigma approaches the service sector in general is more aware of these new methods. This finding could mean that awareness of these new methods is not finding its way into the manufacturing arena effectively and methods may need to be explored to improve this.

Interestingly keeping in mind the previous findings, manufacturing is statistically more concerned over the increasing levels of environmental legislation than the service sectors. Maybe if the manufacturing sector was more aware of "Green" LSS and its potential benefits this could reduce their fears over the increasing legislation. Additionally the analysis also found that in terms of "key drivers to go green" manufacturing placed legislation higher than the service sector. It could also be argued that the manufacturing sector feels more targeted on legislation than service sectors due to it potentially producing more harmful emissions and wastes, but this would need to be proven.

When asked about the LSS tools and techniques that should be developed into "Green" versions, the manufacturing sector saw the need for "Green 5S" as higher than service sector organisations. This information would be taken into account when developing the ELSSSA tool in section 8.

7.2.3 Company Structure

Compared to the 2 previous factors analysed there were less significant differences with company structure types. There were still 3 main areas however that they were statistically different.

Firstly it was found that LTD company structures reported having a greater perceived level of environmental benefit from the deployment of LSS within their organisations than PLC structure types. This is an interesting finding however it is unclear why this is so and further research would be required to try and clarify this.

The second key difference between the structure types was that of the new "Green" Lean and/or Six Sigma approaches sole traders and partnerships had the highest awareness, whilst PLC businesses the least. Reasons for this could be that many Sole traders and partnerships who responded to the survey are possibly consultancy and training businesses. These businesses encounter many different clients and are exposed to a wider range of new innovative ideas and concepts.

The third key difference found regarding environmental concerns was that small companies such as sole traders and partnerships were statistically less concerned about air quality when compared to LTD organisations and PLC's.

7.2.4 LSS Role

The analysis found that in terms of the use of LSS in their respective businesses it was shown that the category containing MBB, BB and trainers had been using LSS longer than the other 2 categories. This finding is unsurprising as it would be expected that individuals who have had more extensive training to have been using LSS longer than say a yellow belt.

LSS role types such as yellow belts and team members also perceived that the environmental negative consequences from deploying LSS were statistically higher when cross tabulated with BB and MBB. With this insight it could be that BB/MBB role types are closer in their understanding and experience of the environmental negatives and view this as less of an issue. Another reason could be that BB/MBB role types are more "pro" LSS and are therefore more biased in favour of the approach than other role types and aren't "seeing the wood for the trees"

The final key difference found with LSS role types was regarding the impact of increased levels of environmental legislation. Yellow belts, champions and team members had higher concern levels than other role types. As this group work on LSS on a part time basis when compared to full time members such as MBB/BB it could be that they are closer to other issues such as environmental legislation.

7.2.5 LSS Experience

Of the 5 areas of focus from the overall analysis, the most significant statistical differences were found within the analysis conducted by LSS experience.

LSS users with 5-10 years' experience were the most consistent in their achievement of their projects reaching company goals, even more so than users with 10+ years' experience. On initial inspection this does not appear to make sense however when we analyse previous findings from analysis in Section 7.2.2 and take into account the increase of service sector LSS projects and its success when compared to manufacturing, a sensible explanation can be generated.

It was also found that users with 5-10 years' experience of LSS had higher levels of environmental benefits than the other experience groupings. Again logically you would expect users with 10+ years' experience to have more knowledge in this area, however the analysis also showed that users with 5-10 years' experience also had higher awareness of "Green" versions of LSS.

LSS users with the least experience of the approach were unsurprisingly found to have the most concern over the knowledge of the approach compared to the other 3 groupings. Similarly, they also had less knowledge of new approaches such as "Green" LSS than the other groups probably because they are less experienced members of the LSS community.

Of the LSS tools and techniques that were perceived as having the highest value if developed into "Green" versions, users with 0-2 years' experience statistically viewed "Green Kaizen" and "Green Process Mapping" of less value than the other 3 groups. It could be that those with less knowledge of LSS were less probable to acknowledge the benefits of developing these two tools types in comparison to the other more experienced groups.

7.3 Summary

This extensive set of analysis tests and statistics has clarified vital information about the global LSS user community and the similarities and differences that exist be it by global location, company structure, business sector, LSS role and LSS experience.

The outputs of this analysis will provide focus and direction for the development of the ELSSSA tools and framework covered in the next 2 sections. Where similarities exist, the framework will be developed in a generic manner; where key differences exist as a result of the analysis it may be necessary to develop unique/bespoke elements for the tools and the framework.

8 Research, Development and Implementation of a ELSSSA Methodology

8.1 Introduction

Following the critical analysis of the Global LSS survey data the next part of the research was to develop a bespoke Environmental LSS (ELSS) tool and in addition the ELSSSA methodology.

This section has the following aims and objectives: -

- To evaluate and select a suitable LSS tool and/or technique to be developed into a bespoke ELSS tool
- To develop, test and implement the ELSSSA methodology in an appropriate organisation
- To provide analysis and feedback from the ELSSSA methodology implementation

Taking into account the objectives identified above it was necessary to outline a structured critical path of tasks that needed to be completed. To develop this structure the researcher brainstormed (Bouchard 1971) the tasks that were required and sequenced them in order. The structure this section is depicted in Figure 8.1 below: -

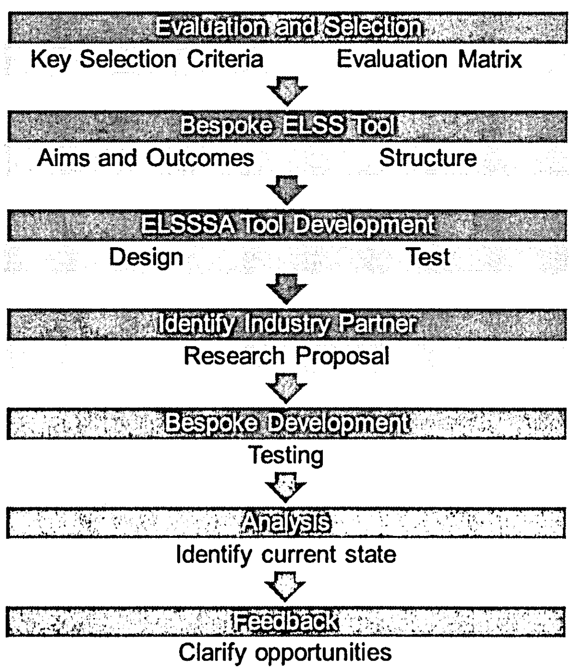


Figure 8.1: ELSSSA Methodology development approach

8.2 ELSSSA Methodology Evaluation and Selection

8.2.1 Analysis Findings

The results in Figure 5.29 of the survey specifically clarified which tools the Global LSS user community viewed were of value if developed into environmental versions of traditional LSS tools and techniques. Of the 22 tool types the top 5 of these were analysed in section 6, these were as depicted in Table 8.1: -

LSS Tool	Value if developed into Environmental LSS tool and technique (%)
7 Wastes	79.38
5S	68.29
VSM	56.54
Kaizen	55.43
Process Mapping	55.21

Table 8.1: Top 5 LSS tools and techniques deemed to be of value if developed into "Green" Versions

Process Mapping is not specifically a LSS tool even though it is frequently used on LSS projects. Taking into account this factor and that there are some similarities to VSM, this would not make it as good a selection for the ELSSSA methodology. Also VSM offers many superior benefits over Process Mapping operationally such as being more focused on identifying specific waste types and its ability to quantify improvements from current and future state maps.

It was also decided at this point not to develop an ELSSSA Kaizen technique as Kaizen (Holpp 1989) is more of an approach for continuous improvement which could include many of the tools and techniques discussed such as VSM or 5S.

This left 7 Wastes, 5S and VSM as potentially the most suitable for development as ELSSSA tools that would be assessed against a number of key selection criteria.

8.2.2 Key Selection Criteria

For the 3 remaining LSS tool types the following key selection criteria were identified: -

- Tool popularity
- Complexity
- Applicability
- Audit Compatibility
- Questionnaire Structure
- Analysis
- Feedback and recommendations

8.2.3 Evaluation Process

Tool Popularity

When developing the ELSS tools it is appropriate to base the development of these new methods on existing tools that are popular as users will be able to associate with them.

From the results data in Figure 5.12 it can be seen that 5S is the most widely used tool globally. For this LSS tool 84.48% of the respondents claimed to use this technique. This contrasts with VSM which is 7th in the list of popular LSS having returned 76.94% of the respondent's views. Finally 7 Wastes is classified as the 8th most popular LSS tool with 72.95% of the respondents claiming to use this technique.

Complexity

5S is most probably the easiest tools to learn and use out of the three tools down selected in this section. The author has trained over 1500 people in these 3 tools and users grasp 5S easier than both 7 Wastes and VSM. From discussions with various clients including Rolls Royce, 5S is seen as a good "starter" LSS tool that can garner quick results and benefits.

7 wastes are easy to relate to in principle however businesses find it more difficult to implement as a tool/technique in the workplace. Some organisations find difficulty in the true quantification of the wastes in particular and/or the potential for cross over with certain waste types.

From the researcher's perspective VSM is the most difficult for users to learn and conduct effectively in their working environments. Users new to the approach can take time to understand the different elements that make up the value stream and create their own maps correctly without errors.

The complexities of VSM's vary considerably from business to business but many organisations can struggle to develop them in particular where they have a multi-layered value stream or if they have a wide number of product/service ranges to map.

Applicability

As discussed previously in section 7.1.4 and depicted in Figure 5.29 the global LSS user base has identified that 7 Wastes is perceived as the most suitable "Green" LSS tools and technique with a response of 79.38%. 5S in comparison had a return of 68.29% and VSM 56.54%.

Researching all three of these tools further reveals that in addition to the responses above, companies are in limited quantities developing their own Green LSS tools. As identified in the literature review section 2.3.4 the EPA in the USA have developed their own Lean and the Environment toolkit and this discusses and outlines 6S, Environmental 7 wastes and VSM.

Audit Compatibility

The ELSSSA methodology must be based on a LSS tool that is easily audited. From the research conducted in section 3.3.1 it was found that with traditional LSS assessment or audit methods most frequently assess 5S. However these assess methods also commonly assess 7 wastes, and this is usually conducted by each individual waste type in order to clarify where the most significant waste types exist. Figure 8.2 below also clarifies other tools that are also assessed including SMED (Quinlan 1987) and Visual Controls (Jackson 1996), however VSM is not a tool commonly audited using these assessment methods.

7 Wastes Over Production		7 Wastes Waiting Time		7 Wastes Defects		7 Wastes Processing	
Quantities produced in accordance with demand	3	Large queues and bottlenecks in area, no balancing of in cell	1	Products checked line-side against customer specification, high yield evident	4	Most materials close to processes, correct use of feeds and speeds on the facility	3
7 Wastes Movement		7 Wastes Transportation		7 Wastes Inventory		5S Address and Place	
Operator movement with cell is low. High levels of time spent looking for tools, going to stores	2	All processes close together minimal transport required	4	Components produced in required batch sizes by customer Obselesance in warehouse	3	Many tools are unmarked and have no set location within the cell. Tools also lost and broken	1
5S Working Environment		Visual Control Improvement Boards		Visual Control Production Control Boards		Visual Control Skills Matrices	
Most cell safety areas and pathways marked Some untidy and unclean areas for improvement	3	No information of cell improvement activities and meetings	1	Low evidence on cell reporting of actual vs planned production and budget control	2	Employee training is currently at a low level and is not evident on the cell	2
KANBAN		Poke Yoke		Standardisation		Set Up Reduction	
No synchronisation of processes but are close coupled	2	No use of mistake proofing methods in evidence	1	No SOP's in cell for operators to adhere to.	1	No use of toolset, high internal & external set- up times in cell	1

Figure 8.2: Example of Traditional Lean Assessment Scoring Matrix

Questionnaire Structure

The proposed ELSSSA will follow a questionnaire type structure similar to that developed in the research for the convention 5S sustainability audit in section 3.3.8 both 5S and 7 wastes are well suited from an auditing perspective to this type of structure when taking into account the combined use of leading questions and observational questions both of which are typical of traditional Lean audits. VSM would be more complex to develop around a questionnaire structure but not impossible. It would however require significantly more time to adapt and develop to further this LSS tool into a questionnaire type structure that could be applied in many different industry sectors in a generic method

Analysis

The industry testing of the pilot for conventional 5S Audit tool that was developed in section 3.3.9 proved there were no issues with conducting the analysis with 5S. By modifying the standard 5S questions into E5S questions the analysis of this should follow the same method therefore no issues should arise. Also proven in the POC phase was that with 5S the analysis could be conducted quickly using the modified SNAP 9 software.

The capability of an environmental 7 analysis wastes using the SNAP 9 software tool would very similar to that of 5S; with weighted scoring for each of the different wastes types indicating where focus on improvement should occur. Analysis using the SNAP 9 software tool would require significantly more develop and programming to provide a viable assessment method.

Feedback and Recommendations

Following the lessons learnt from the POC using conventional 5S the feedback and recommendations were provided quickly and effectively to the industrial clients. The conversion to E5S should be no different as the main change is the environmental content of the questions.

Feedback for environmental 7 Wastes would follow a similar structure to the E5S therefore there should be no additional complexities. Due to the added intricacies of VSM this would make the feedback and recommendation process more difficult to conduct and more skills and knowledge would be necessary for this vitally important part of the process

8.2.4 Evaluation Matrix

The following ELSSSA evaluation matrix (Table 8.2) was developed and using a rated scale of 1-10 for each of the selection criteria each LSS tool was assessed using the discussion elements from 8.2.3. From this analysis it was deemed that 5S would be the most suitable tool.

	LSS Tool Type		
Selection Criteria	5S	7 Wastes	VSM
Tool popularity	10	7	6
Complexity	10	8	6
Applicability	9	10	8
Audit Compatibility	9	8	5
Questionnaire Structure	9	9	4
Analysis	8	8	5
Feedback and recommendations	8	7	6
Total Score	63	57	40

Table 8.2: ELSSSA Tool Evaluation Matrix

Overall the evaluation process considered development of E5S and subsequent ELSSSA for the 5S approach to be of the most value for the next part of the research. The ELSSSA for the 5S approach will from this onwards be called the Environmental 5S Sustainability Audit (E5S-SA)

The main reasons for selecting this tool over the others were fundamentally it's compatibility towards being developed into an audit process and its simplicity to implement and understand from a stakeholder perspective. Sustainability of 5S can be a problem in businesses but this would not be a reason for not selecting 5S as the E5S-SA would clarify if sustainability is an issue in an organisation. This would therefore be advantageous as this would communicate this issue to management who may not be aware of the problem of sustainability of 5S in their organisation.

8.3 E5S Development

The development phase was split into 2 major parts. The 1st part entailed developing the E5S structure and associated questions for each of the 5 steps of the 5S process. The 2nd part involved taking the lessons learnt from the development of the conventional 5S POC from section 3.3.8 and embodying these changes into the E5S-SA tool

8.3.1 Aims, Objectives and Outcomes

Careful consideration was placed on the aims and objectives of the methodology of developing E5S as a backbone to the E5S-SA methodology. These are summarized below:

Aims and Objectives

- To enhance (not replace) the established and proven 5S process
- To identify and consider environmental issues (Aspects and Impacts) within the workplace as part of the 5S programme
- To use less material and energy such as water, chemicals, electricity and subsequently reduce emissions
- To reduce the overall environmental impact within the workplace to meet existing or forthcoming legislation
- To improve overall quality including reducing defects and rework

Outcomes

The development of E5S should deliver the following outcomes:

- Raised awareness of environmental impacts within the workplace
- Improved environmental sustainability
- Reduction in the impact an organization has on the environment
- Involvement of employees at all stakeholder levels on environmental issues within the workplace
- As structured approach that is conducted on a regular basis

8.3.2 Structure

Prior to developing the E5S-SA methodology, the outline structure for E5S needed to be defined. Conventional 5S as demonstrated in the POC in section 3.3.8 consist of 5 phases. Each individual phase was examined and adapted towards the aims and objectives clarified above.

Environmental Sort Phase

With conventional 5S the objective of the Sort phase is to identify what is needed in the work area and what is not needed. The process for conducting this is most commonly called "red tagging" (Hirano 1996) With E5S it is proposed to utilise a "green tagging" process. This would be used on any items that are identified that are hazardous to the environment, safety and/or people. Operationally the green tagging process is not proposed to replace the red tagging process; instead it would work alongside it.

In practice the process improvement team members would identify the specific work areas that would be assessed and secondly clarify the specific items within that work area to be assessed. A green tag was subsequently developed (Figure 8.3) which took the basic elements of the traditional red tag and added bespoke environmental elements

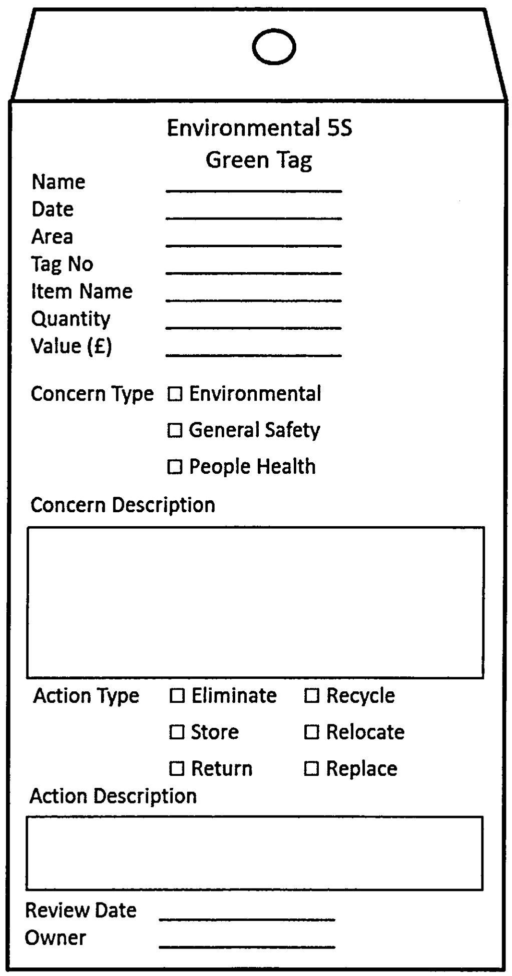


Figure 8.3: Environmental 5S Green Tag

The main visual difference between the green tag and the red tag is the inclusion of the specific concern types and a description of this concern. Also added in the action types was the option to select recycle which is not a conventional option on a red tag and in addition to replace where a viable alternative was sought.

Operationally any item that is green tagged should be quarantined in an approved area and subsequently be assessed by an appropriate internal qualified/trained employee or external 3rd party. If an item is deemed to be dangerous to employees if moved, then it should remain in its place until it has been assessed and advice clarified on how it should be handled safely.

In situations where an item is identified to be a concern but it is deemed to be an unavoidable functional requirement as part of a process or system, a viable alternative may need to be investigated by the team that has a reduced level or ideally no environmental impacts. The team could utilise traditional LSS tools such as Brainstorming (Parnes 1959) to help clarify potential solutions.

It is important at this stage to have a database of some kind to store the records of the green tags and to log the benefits. Also of value is to conduct reviews which share the lessons learnt at this stage of the E5S process. For example, there may be potential to "read across" certain viable alternatives that have been identified during the green tag process to other departments or functions either within the business or to other divisions and even global locations. Thus, this could deliver an even bigger contribution to the reduction of environmental impacts.

Environmental Straighten and Set Location Phase

On completion of the environmental sort phase all the remaining items need to be organized depending upon frequency of use whilst simultaneously considering the potential risks and impacts on the environment. Any hazardous items need to be clearly labeled in line with standards and guidelines specific to industry sector and global location. If not already in place in the working environment there should be colour-coded rubbish stations to encourage the philosophy of reuse / reduce and recycle.

In organisations where there is the use of hazardous chemicals or environmental wastes that are an output from their processes, storage needs to be considered. Storage methods should consider appropriate types of containers and storage for the given workplace.

For example it may be advisable to have any stored hazardous materials off the floor and these items will need to be adequately sealed off when not in use. In addition it may also be advantageous to implement visual controls such as colour coding of flooring areas to highlight where environmentally harmful chemical are stored within the workplace. To embrace the environmental theme further these painted floor areas could use water based paints to minimise the environmental impact of any modifications.

By embarking on these types of practice within the workplace would yield the following types of environmental benefits: -

- Better visibility of environmental risks
- Improved environmental awareness and control
- Less damaged/scraped parts
- Less environmental waste.
- Reduced quantities of unknown, lost and obsolete parts and equipment

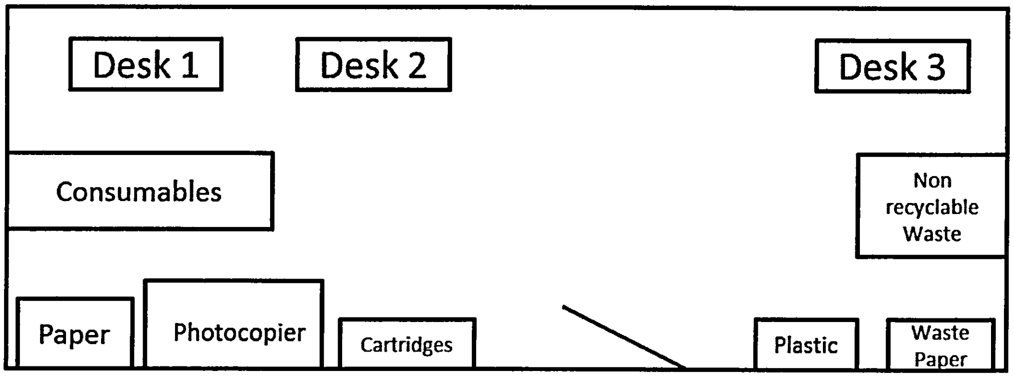
Environmental Shine and Sweep Phase

As with conventional 5S once the sort and set location phases are complete it is much easier for employees to notice where there are abnormal occurrences in the work area when they conduct a thorough shine and sweep.

The key difference with the environmental shine and sweep phase is that it is more focused on environmental aspects and impacts. Taking into account these aspects and impact as discussed in Figure 2.5 employees would typically be looking for any wastes in the incorrect area and cleaning down designated areas at certain time intervals.

At this stage the roles, responsibility zones and plans needed to be for the organisation. The approach would utilise environmental check-sheets as part of daily, weekly and monthly routines, an example of a typical shine and sweep check sheet is depicted in Figure 8.4.

Environmental 5S - Shine and Sweep Schedule Sheet



Environmental 5S Area ____________

Process Owner ____________

No	Who	What	How	Standard	Clean Time	Day	Weekly	Monthly
1	JM	Cartridges	Wipe	Clear and clean	2 mins		O	
2	GT	Waste paper	Visual Check	Correct waste type	3 mins	O		
3	FR	Plastic	Visual Check	Correct waste type	3 mins	O		
4	JM	Consumables	Wipe	Clear and Clean	5 mins		O	

Figure 8.4: Example Environmental 5S Shine and Sweep Schedule Sheet

Depending on the working environment being assessed during the shine and sweep phase in addition to the example in Figure 8.4 below are list of suggested things to look for: -

- Any types of leak e.g. water, emissions, pipes or hazardous materials
- Waste in the correct recycling bins
- Correct filters being used, are they clean
- All drains clear from debris or are hazardous material being evacuated down them
- Most environmentally appropriate cleaning materials being used
- Check for any fumes, dust or unpleasant odours or smells in the workplace
- Recycling bins emptied at regular intervals

Environmental Standardise Phase

The aim of the environmental standardize phase is no different in its ethos than conventional 5S; to maintain and consolidate the first 3 5S's by creating standardized procedures. However as with the former elements of the Environmental 5S clarified thus far, this phase will continue to focus on the environmental aspects and impacts. By standardizing and maintaining a clean and safe internal environment this will reduce the subsequent impact on the external environment.

This phase relies heavily on the use of visual controls within the designated workplace. This will help clarify what is an environmental abnormality and/or hazard within a work area and make it more visible. It is also proposed that within the workplace, environmental indicators are present that will provide appropriate limits that are to be met. These limits may need to be set by a qualified member of the team, for example, from an environmental function.

Also of high value within the phase is to implement the use of positional markers for items that constitute environmental waste or risk within the workplace. These again should be standardized across all deployments in the organisation. Examples of these positional markers in the workplace include the use of labels on taps to remind people to turn them off when not in use, labels on different waste bin types for recycling purposes, markers on photocopiers or computer monitors and light switches.

Messages on these markers that make users think about the wastes resulting from leaving devices switched on can be useful to put things into perspective. For example a photocopier left on overnight wastes enough energy to make 30 cups of tea or leaving a computer on overnight produces enough CO_2 to fill a double decker bus (Carbon Trust 2012).

Another important aspect of the proposed environmental standardize phase is to create Environmental Standard Operating Procedures (ESOP's) within the workplace to reduce any variability in terms of environmental impacts and also increase the level of predictability within the workplace. The use of

ESOP's will provide a backbone for improvement which will in turn help reduce levels the 7 Wastes which will in turn reduce potential environmental impacts.

To create an effective ESOP the following key points need to be clarified by the team members as depicted in Figure 8.5

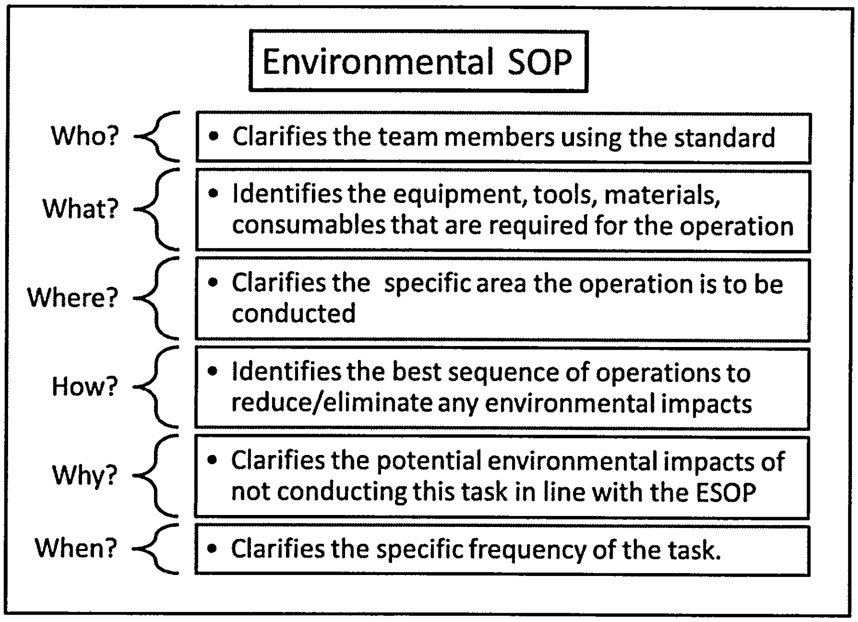


Figure 8.5: Defining points of an ESOP

Environmental Sustain

The Environmental Sustain phase takes the core principles of 5S and develops them further to sustain environmental improvements established in the earlier phases and encourages the philosophy of continual improvement via regular "Check, Act, Plan, Do cycles.

A fundamental part of this phase to ensure sustainability is the use of an audit method as this will provide an indication of how well the different phases of the E5S approach are doing for each designated workplace area and clarify where problems exist that need to be improved. Operationally the audit process should only take 5-10 minutes to complete and it should involve everyone in its assessment so that each member is aware of the issues and also to ensure consistency. Where differences exist in the audit there could be a lack of training or understanding which may need to be understood and improved. It will also help clarify whether consistency is present in the understanding of the different environmental risks and hazards within the workplace. A full description of the E5S-SA process and its development is clarified in the next part of this section.

The environmental sustain phase should involve all stakeholder levels to ensure not only general commitment from operations but also the all-important management commitment which was clarified as the most important concern towards the sustainability of LSS projects from the Global LSS survey.

It is proposed that management within an organisation implementing E5S provide the necessary encouragement the other team members. They must also allow the team members the time and any associated resources required in order to conduct and maintain the E5S within the designated work areas. The aforementioned management commitment to the process can be achieved through regular "boardwalks" which involve all the major stakeholders and managers need to attend these as a show of their commitment. These "boardwalks" must take place in the designated work area so that managers can witness with their own eyes the environmental concerns and potential resulting impacts. This will also help galvanise the team spirit in particular for operational staff who will witness this commitment to environmental sustainability from management.

In addition there are various other methods that management can employ to increase sustainability of the proposed E5S. The provision of environmental books and videos which promote the ethos of environmental management can provide a catalyst for employees and may generate further improvement ideas by increasing their knowledge and expertise.

Also of value and worthy investment would be basic training for employees in environmental management. This would help bridge the gap between the use of LSS tools and Environmental Management. Providing employees with knowledge and awareness of the environmental aspects and impacts and well as basic awareness of approaches such as ISO 14001 as discussed in section 2.4.4 would assist in facilitating the combined methodology. Awareness and experience of team members should be written on a workplace based skills matrix and this should also include any planned training.

There are numerous organisations in the UK (e.g. WRAP/Envirowise) that provide free introductory courses to organisations in particular SME's. Companies therefore with an understanding of 5S but little awareness of environmental management would therefore be advised to undertake these types of events.

Other types of internal promotion and awareness training of the E5S approach could be in the form of internal seminars to demonstrate the principles and benefits to employees or for large organisations this could manifest itself by the way of visiting other sites or divisions to view best practice and benchmark themselves. Sharing the lessons learnt is another way of sustaining the potential environmental benefits.

It may also be beneficial to install posters in the work areas that promote the ideas and the potential environmental impacts of not sustaining the E5S and to publish the outcomes of the E5S using company newsletters and intranet sites.

Many traditional 5S deployments use Storyboards (Tapping and Shuker 2003) to communicate the improvement journey that has been undertaken and this is an excellent method to demonstrate what has been achieved to other teams. This can in many ways help motivate other areas to improve and even promote a healthy competitive nature within the workplace. The Storyboard should describe the environmental reasons for conducting the activities and how it relates to the overall organisational strategy and highlights any problems and how these will be mitigated.

The final method that can be employed in the Environmental Sustain phase is the use of reward and recognition schemes that celebrate the successes of deploying the E5S in the workplace. This could be the form of environmental suggestion of the month for example and the resulting event should invite the different stakeholder types who have benefits from the improvement. Invited stakeholders could include internal operational employees and management but also customers, suppliers and even the local community if there has been a significant benefit from an external environmental perspective.

8.4 E5S-SA Primary Design and Testing

8.4.1 Design

Within the research methodology (Section 3.3) a basic design had already been formulated and tested for the conventional 5S audit. Following feedback from recipients and taking into account the proposed structure for each phase of the Environmental 5S, the next steps were to redesign the structure and format of the E5S-SA. These changes are summarized below.

Structured Audit Sections

To improve the overall structure and purpose of the E5S-SA, separate sections were created to demonstrate which stage of the audit the user was at. These sections were:

- Background information

  Basic information about the employee conducting the audit is collected within the workplace including age, gender and length of company service.

- Organisational Profile

  Asks for the department or function that is to be audited and the specific workplace area. It also clarifies the organisational level of the auditor from operational staff through to director levels. Finally it asks for the audit date so that it can be tracked.

- General 5S Questions

  This asks for general information on 5S for the auditor including if they have received training in 5S and the duration that they have been using the approach. Finally it clarifies their audit role which they can state a choice of 3 options. These options are 5S trainer, department/area employee or external 3rd party assessor.

- E5S-SA Questions

  The questions in the final section which makes up the main body of the audit are structured as with a conventional 5S audit created in the POC in section 3.3. However the questions for each phase of the audit have been developed taking into account the environmental 5S structure in section 8.3.2

In addition for each phase there are 5 questions with a scaled choice ranging from "never" to "always" for the user to complete. Finally the auditor has the option to add any positive comments for each phase and also any negative comments. This will help clarify best practice and also potential opportunities to improve which could impact the long term sustainability of the Environmental 5S approach.

Addition of a Title Page

A title page was added which clarified the objectives of the E5S-SA and identified the need for the audit and also contact details in case of any questions, or problems with the Audit.

Insert Page Breaks

The previous method had the recipient complete the entire audit in one continuous scrolling page. This format did not flow particularly well and if a question was missed out the user would have to return to the part of the audit where the error occurred, which could be frustrating and time consuming. Therefore the audit was given page break inserts to remedy this and also to add structure to and noticeable division between each section.

Additional Departments / Functions

The original had 7 different choices of departments / functions. Following feedback from the textile sector from the original pilot study in section 3.3.9 this choice was researched and increased to 15 to broaden the appeal and make it applicable to a wider range of companies.

Area Assessed Question

The audit asks the recipient their specific function or department; this was added after feedback from the basic 5S audit asked for an extra question on the specific area within their function or department.

Organisational Level

This question was modified slightly after collaborator feedback identified the addition of support staff as a requirement and addition of more specific roles including director and manager to replace middle and senior management choices.

Revised Graphics

New images were added to the audit to relate to the environmental theme for each of the E5S phases. The background colour was also changed from blue to green to continue the environmental theme.

Implementation Tips

A key addition to the E5S-SA was the incorporation of implementation tips for each of the E5S phases.

8.4.2 Validation and Testing

Validation and testing for the E5S-SA would be split into 2 phases. Initially internal validation would be conducted to eliminate any potential bugs and iron out any obvious mistakes or problems that may be present in the tool.

The 2nd phase or external validation and testing would be more on a practical level to gauge external opinion of the design, its ease of use and its application within business scenarios.

Primary Internal Validation and Testing

Following the bulk changes to convert the convention 5S audit to an E5S-SA, testing was necessary to prove the changes and to ensure minimal errors and gain confidence in its robustness.

The E5S-SA was generated in preview mode within SNAP 9 and some minor alterations made to the page breaks and some grammar mistakes removed. The next stage was to publish the audit and manually complete and submit mock audits to test that no faults occurred.

Subsequently checks were made on the receiving of the correct number of audits and each audit checked for any errors. No errors were found at this stage, therefore the final check involved taking the published web HTML file and hosting this and sending the link through to fellow internal users of 5S to complete the audit. These users had widespread experience of 5S in a range of industry sectors and clearly understood the 5S process from an operational perspective.

Primary External Validation and Testing

Following internal validation and testing it was deemed that external demonstration of the E5S-SA would be useful before approaching industry sectors to implement the use of E5S-SA. This would enable unbiased feedback of the approach.

A workshop of the E5S-SA was developed and organised at LSS conference events in the UK and USA which was a useful vehicle to demonstrate the concept and gain useful feedback. The workshop itself demonstrated the methodology and its ability to measure an organization's effectiveness in using 5S within a 'green' context. Other important factors of the workshop were the flexibility of the methodology and that it can be applied within virtually any function in a company or sector.

Participants at the workshop also learned from the demonstration how the E5S-SA provides a means of measuring the level of achievement within various functions of an organization across each phase of the Environmental 5S program and at all levels from general operations to Senior Managers. In addition the participants were shown how to apply the E5S-SA to develop insight into the current environmental awareness in their own organisation.

The attendees from the event came from numerous industry sectors and global locations and were overall very positive about the concept and were also keen to engage in the practical elements of the workshops and provide good discussion points and insights.

8.5 Industry Sector Selection

8.5.1 Introduction

Following the successful completion of primary internal and external testing of the E5S-SA tool it was necessary to conduct "real life" testing to prove the concept and also to make any changes required to improve the overall robustness, capability and alignment to actual business scenarios.

The following key selection criteria were sought from a suitable company to maximise the overall effectiveness of the study: -

- Active users of 5S in the workplace
- Interest in the "Green" aspects and potential benefits of 5S
- Ability to provide a minimum sample of 30 responses
- Open to the ethos of the research and commitment to its objectives
- Willingness to commit to stakeholder reviews and communications

8.5.2 BAA Glasgow

The basic 5S POC without the environmental element had already been tested in two different sectors namely textiles and chemical and both of these had shown promising results. Either of these organisations and their sector types would have been highly suitable for the E5S concept that had been developed, due to the inherent wastes and lack of control within the workplace.

Following discussions with various industry sectors a high level of interest was gained from BAA Glasgow following discussions and demonstration of the concept at a UK LSS conference. Collaboration with the transport sector which is frequently in the public eye in relation to environmental sustainability (Graham and Guyer 1999) suggested that this would be a good testing site for the E5S-SA tool.

BAA Glasgow was undergoing an extensive Lean Six Sigma programme implementing the approach through many different departments and functions. They had been training and implementing 5S for around 6-9 months within their organization and recognized the benefits of this highly used and respected core LSS tool.

Taking into account the key selection criteria (Section 8.5.1) for a suitable company, BAA Glasgow were deemed to be an appropriate organisation at being able to fulfil these requirements. They recognised that 5S combined with Environmental management could provide them with improved sustainability of their 5S programme and that the audit method could help focus effort in the right places within the business.

8.6 Industry Case Study BAA Glasgow

The following case study details the agreed proposal for the research on the development and testing of the E5S-SA across a range of departments. It also discusses the outcomes of the research in the form of analysis based the responses to the E5S-SA and the resulting feedback and recommendations provided to the stakeholder team at BAA Glasgow.

8.6.1 Outline Research Proposal

Initially it was agreed that a proposal needed to be developed and presented to the key stakeholders within BAA Glasgow. The outline proposal for the research to be conducted over a 3 month period is listed below:

- To demonstrate the E5S principles and E5S-SA concept methodology to key stakeholders
- To collect basic company information (user types, departments, stakeholder levels etc.) and modify the methodology (assessment questions) to meet BAA specific requirements
- To test the E5S-SA method with users
- To collect results and to conduct analysis
- To provide presentation feedback and recommendations

Subsequently a meeting was organised with BAA Glasgow which included director level employees as well as process improvement team members. At the meeting the principles of Environmental 5S were demonstrated including its aims and key outcomes (Figure 8.6) and it also guided them through the individual phases from Environmental Sort through to Environmental Sustain.

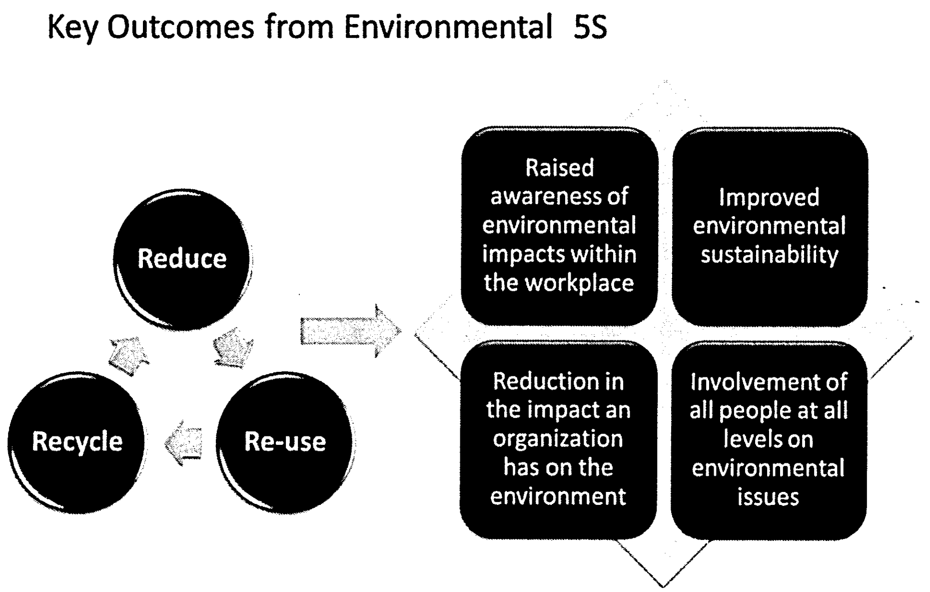


Figure 8.6: Key outcomes from E5S

Also demonstrated were the justification behind the E5S-SA and the process flow of the assessment as shown in Figure 3.4 but from an environmental perspective and the case study POC for conventional 5S.

The final part of the meeting focused on the concept for the E5S-SA that had been demonstrated at the workshops in the UK and USA. BAA Glasgow could see the potential benefits to their own particular industry sector, which they acknowledged was very much in the public eye with respect to environmental impacts. Following the meeting it was agreed that the researcher would work with two LSS Black Belts to develop the E5S concept to their own bespoke requirements.

The 1st Black Belt's role was Head of Continuous Improvement BAA Glasgow and was responsible for the successful deployment of Lean Six Sigma within the organisation. Within the context of this project they would assist with the coordination of key stakeholders and apply influence in completing milestones. The 2nd Black Belt role was as Integration manager and their responsibility within this project was to gain operational support with responses from the workforce and use feedback gained from the audit towards the deployment planning process.

8.6.2 Bespoke Development

BAA Glasgow were happy with the existing structure of the E5S-SA and it was agreed that the basic structure of the approach and the associated questions should remain in the 'as is' state. The main changes requested by BAA Glasgow would be to the leading questions within the audit so that they would be more in line with the unique circumstances at their own organisation.

The main changes to the E5S-SA are summarized below:

BAA Organisational Profile

Several changes made that were specific to BAA Glasgow. These changes included adding their unique functions/departments and specific areas assessed. These changes can be viewed in the appendix figure D.4.

General Environmental Questions

A new section of the audit was incorporated which including 3 general environmental questions (appendix figure D.6). These were designed to add additional analysis and insight into the cultural element of each department with respect to environmental concerns, legislation and the combination of 5S with environmental management practices.

Graphics

Enhanced graphics were added including BAA logos and other bespoke graphics created specifically for the audit to make it more visually appealing for the user and to provide it with a corporate identity to make it look like a BAA product.

Progress Bar

SNAP 9 has a function with enables the recipient to view how far through the audit they are as they progress through the process. This provides the recipient with awareness of how complete the process is and a sense of achievement, and should reduce the risk of recipients not completing the audit

Webpage following Submission

SNAP 9 allows the author to select a webpage of their choice following submission of the audit. In this case it was felt prudent to insert BAA Glasgow's homepage to increase the employee buy-in of this being a BAA Glasgow specific product.

8.6.3 Internal Testing

Following completion of initial development of the E5S-SA internal testing was conducted to capture any problems or limitations with the tool. The E5S-SA initially was previewed without publication within SNAP 9 in preview mode to validate the overall aesthetics and functionality. The tool was subsequently published and previewed as a web HTML file and the audit submitted by the author and associates several times to test its robustness and usability. All the submissions were received by the author with no issues, however following comments from associates several changes were made following this initial testing, these are summarized below.

Text Comment Boxes

The text comment boxes were two small, even though the user could add as much text as they wished only a single line was visible which could either mean the recipient would leave a short message or not bother because they don't think enough space is available. This was increased to 6 visible lines but more could be added if the recipient wished to do so, an example of this can be viewed in appendix figure D.7 relating to question 16.

Question Numbers Visible

The original audit did not show the recipient the question number that they were on at any point in time however during internal testing it was deemed that this could be problematic. The reason for this being that if the recipient forgot or missed a question the tool would inform them that they had done so and the question number they had not completed. As the question numbers are only visible to the author and not the recipient this would potentially cause confusion and possible frustration with the Audit.

Research within the SNAP help files showed that by selecting 'all styles' within the style mode function and subsequently selecting 'show' from the toolbar topic menu would switch the question numbers 'on' automatically on screen without the need for manually added the numbers.

8.6.4 Validation and Testing with BAA Glasgow

The E5S-SA was now ready for initial validation and testing with BAA Glasgow before the pilot deployment within selected areas of the organization. The published audit was inserted into a host webpage and a link created which was emailed to the process owners at BAA Glasgow. The owners subsequently completed the E5S-SA and this returned to the researcher's inbox and into SNAP 9 with no problems.

Checking through the respondents returns the results showed no major issues with the scoring and the graphs and table produced. Feedback comments from the process owners at BAA Glasgow led to some minor alterations being made to the BAA employee 5S experience questions in the audit. Specifically this was regarding questions on the training received for 5S and their specific 5S role. An additional question was added asking the recipients of the benefits they had achieved from the 5S deployment. This can be viewed in appendix figure D.5.

8.6.5 Implementation

Following extensive development and testing, the final version of the E5S-SA was judged to be ready for roll out at BAA Glasgow. Following discussion with the stakeholder teams the following departments were going to take part in the implementation: -

Functions/Departments

- Airport Senior Management
- Airside Operations
- Business Support Services
- Customer Services
- Development

- Finance
- Fire Service
- H&S
- Maintenance
- Property/Retail
- Security

The newly published audit was emailed to the designated process owner at BAA Glasgow who subsequently issued this to all the relevant stakeholders from the functions identified above who are using 5S as part of this project.

8.6.6 Results

Audit returns were collected over a 4 week period, this was to allow for holidays and shifts within each department. Overall a total of 36 returns were collected over the 4 week period. The average time the BAA employees took to complete the audit was 10.39 minutes which was only slightly over the 5-10 minute guide time.

As this was the 1st time that the employees had completed the audit it is envisaged that operationally this time would reduce as employees become used to the format and process.

The results for the main elements of the E5S-SA are presented in Appendix E.

Basic Employee Information

The E5S-SA returned responses from 75% males and 25% females (appendix table E.1) and with the highest majority (44.4%) falling within the 40-49 year old age category (appendix table E.2). A large proportion of the BAA employees (44.4%) had been employed by the company (Appendix Table E.3) for over 10 years, and only 5.6% being employed for less than 1 year.

BAA Organisational Profile

Overall the audit yielded responses from 10 of the 11 departments that it was issued too (appendix table E.4). The highest response came from the Airport Senior Management department with 22.2% of the overall population.

Of the 13 locational areas within BAA Glasgow that the audit was delivered to (appendix table E.5), 10 specific areas responded to the audit. The highest response was achieved from Erskine Court which yielded 33.3% of the population.

For the question relating to organisational level at BAA Glasgow (appendix table E.6), 66.7% of the responses for the audit came from Management level. Responses were also achieved from the other 4 internal levels of BAA Glasgow but in much smaller proportions. There was no response from external organisations e.g. management consultants or trainers.

BAA Employee 5S Experience

Regarding 5S training received (appendix table E.7), 50% of the respondents had received training at BAA Glasgow and 13.9% had received training outside of BAA Glasgow. 5.6% of the sample population stated that they had no received training but would like to have it and 19.4% had not received training but were aware of the 5S principles. Of the total percentage of replies 11.1% simply answered that they had no training in 5S.

5S was shown to be quite new to the organisation (appendix table E.8) as 41.7% had been using the tool for less than 6 months. This compares to 8.3% that had been using the approach for 2-5 years and just 2.8% for 5 years or more.

There were a wide range of responses relating to the different 5S role types within the organisation (appendix table E.9) with 28% purporting to have overall responsibility for the area, this compares to 20% being practitioners of the 5S approach. 18% of the population were classed as Champions of the 5S approach and 12% were implementers. Just 2% were trainers of the approach and the same were external assessors. As important, 18.0% reported that they had no 5S role.

The benefits (appendix table E.10) reported thus far by BAA Glasgow from 5S deployment showed that for the overall sample population 22.6% had improved quality, which was slightly ahead of cultural benefits (20.8%). For improved delivery 11.3% of the overall response was achieved, whilst lowers costs were just 7.3%. Disappointingly 22.6% reported no benefits at all from the deployment of 5S.

General Environmental Questions

Encouragingly 72.2% of the BAA Glasgow respondents considered that the combined approach of 5S and environmental practices (appendix table E.11) was of value to their organisation. Only 2.8% did not see the benefit in combining the two methods whilst 25% had not considered this before.

In terms of concern levels for the environment (appendix table E.12) 47.2% were sometimes concerned, whilst 33.3% were highly concerned and 19.4% extremely concerned. No respondents reported to be slightly or never concerned about the environment.

Regarding their concern over the increasing levels of environmental legislation 75% were concerned about this issue and 11.1% were not. 13.9% of the population sample had not considered this question before.

BAA Department E5S-SA Scores

Using the logic created in SNAP survey to apply weighting to the responses for each E5S Phase it was possible to automatically develop an overall table of scores for each department that had been audited. This provided a quick and easy visual of which areas were performing well (Table 8.3) with their E5S programme for each of the different phases.

	Base	SORT Total	STRAIGHTEN Total	SWEEPING Total	STANDARDISE Total	SUSTAIN Total	Overall 5S Total
Base	-	-	-	-	-	-	-
Your Main Department / Function							
Airport Senior Management	-	7.38	12.50	11.75	11.50	9.88	53.00
Airside Operations	-	8.00	14.00	6.00	9.00	0.00	37.00
Business Support Services	-	8.33	18.33	15.33	15.67	7.67	65.33
Customer Service	-	12.50	15.00	10.50	13.00	7.00	58.00
Development	-	5.33	14.67	10.33	10.67	3.33	44.33
Finance	-	-	-	-	-	-	-
Fire Service	-	4.00	5.00	3.50	10.00	8.50	31.00
H&S	-	11.25	15.00	13.25	15.00	11.00	65.50
Maintenance	-	11.86	15.29	10.14	13.57	12.43	63.29
Property/Retail	-	11.50	13.75	12.50	12.00	10.50	60.25
Security	-	13.00	15.00	11.50	10.50	9.50	59.50

Table 8.3: Overall E5S Sustainability Audit Scores by Department

8.6.7 Analysis

From the results above there were a number of key areas that required further analysis. In terms of the responses there was in the researcher's opinion too many responses from the management function. When conducting the analysis it would be more beneficial to gain opinions over a more balanced range of organisational levels (appendix table E.6) in particular operational staff where the response was low.

Of the 5S training received (appendix table E.7) only 50% had been provided by BAA Glasgow. Training for 5S can vary considerably in terms of its content, extensiveness and quality and it is important to have consistency of the overall approach. 13.9% had received 5S training elsewhere and this could be problematic due to the terms just clarified.

Also a total of 36.1% of the BAA Glasgow employees who conducted the E5S-SA had no formal training in 5S. Logically if BAA Glasgow has employees conducting audits without training in the approach this is going to result in poor executed and variable audits. Therefore a clear opportunity has arisen for formal 5S training for those who have not yet been trained and for those who have been trained in 5S outside BAA Glasgow to be trained using BAA Glasgow's own methodology.

The results from appendix table E.8 cement these thoughts further as 13.8% claim to have never used 5S which is considerably less than the 36.1% who have not had any training in the approach. Therefore there are employees using 5S whom have no training at all. Overall duration of using 5S is still relatively low but it is vitally important to gain sustainability of the approach early on and the use of the audit method should help in this respect.

A wide range of responses were garnered for the different 5S role types (appendix table E.9). Of importance was the lack of anyone being designated as a 5S auditor from the 36 responses, and this should be reviewed otherwise it is difficult to see who will set the standard and provide parity. Also worthy of note was that 1 respondent is a 5S trainer and this may explain the lack of training in certain areas and it may be prudent to increase this to help spread the 5S tool more widely in the business. 18% of the respondents reported to have no 5S experience and it is advisable here to examine the stakeholder team organisation to clarify why certain employees have "slipped through the net" and have not being defined a role even though they are taking part in 5S audits.

BAA Glasgow responses to the environmental specific questions demonstrated that employees were concerned over the impact of environmental legislation. The use of the E5S-SA could help reduce these concerns if reductions in environmental wastes were implemented using the approach. They also recognised the benefit of combining 5S and Environmental Management (only 2.8% disagreed) and therefore they were open to this type of approach within their organisation.

In terms of the performance of the 10 different departments from the E5S-SA the overall highest scoring departments were Health and Safety (66.5%) Business Support Services (65.3%). Even though these can't be classed as benchmark scores these departments had a good starting baseline to build on and there could be lessons learnt in their areas that could be passed onto other departments.

The lowest scoring departments were Fire services with 31% and Airside operation with 37%.and recommendations for these two departments can be found in the next section.

8.6.8 Feedback and Recommendations

Following the analysis of the respondents E5S-SA returns, a feedback session was organised with BAA Glasgow. The objective was to deliver the findings and also outline specific recommendations aimed at helping the different departments in gaining environmental sustainability via the use of the E5S Sustainability Audit.

Using the output from E5S-SA, general recommendations applicable to all departments were provided and subsequently more specific advice on a department basis was discussed at the meeting.

General Recommendations

These recommendations are focused at all department types that were assessed using the E5S-SA.

- Additional 5S Training

  It was recommended that all employees who had not been trained at BAA Glasgow in 5S be done so as soon as possible, this would help put all the different departments on a more equal level of understanding and improve consistency of audit returns.

- Awareness and implementation of Environmental 5S

  Within BAE Glasgow some employees were not aware of Environmental 5S and its principles and benefits therefore it was advised that this be provided to all the departments that were taking part in the 5S programme.

- Implementation of Green Tagging Process

  The use of green tagging of environmental wastes and hazards within the workplace was required across all business functions to supplement the existing red tagging process that was in place.

- Combining 5S and Environmental Management

A high proportion of employees at BAA Glasgow recognised the value in combining the two methods within their organisation therefore it was recommended that environmental management work closely with process improvement team members on the Environmental 5S programme.

- Focus on the Environmental Sustain Phase

The final phase of the E5S-SA provided the lowest average score (9.31 out of 20) across all the departments that were assessed. Therefore it is recommended that special focus is placed on this phase on specific areas including the inclusion of a benchmark E5S photo in the work and also regular and transparent E5S reviews with team members. Also efforts should be made to ensure that within the sustain phase that all previous actions from the audits have been cleared otherwise this may impact on motivation within the team. Finally the scoring for the E5S Sustainability Audit should be visible to all stakeholders within the workplace.

- Focus on the Environmental Sort Phase

In terms of a low average score across all departments the Environmental Sort Phase performed very similarly to the Environmental Sustain phase discussed above averaging 9.47 out of 20. Generally more focus is required on making environmental wastes visible in the workplace and the use of green tagging on these wastes which need to be registered and kept up to date. In addition special attention should be made to place any of the wastes in designated quarantine areas and to dispose of any environmental wastes in an environmentally safe manner.

Department Specific Recommendations

Out of the 10 departments that were assessed the following 3 departments were deemed to require additional assistance to improve their overall scorings and sustainability of the E5S approach within the workplace.

- Fire Services

The overall audit score for fire service was the lowest of the 10 departments audited with a score of 31%; therefore the recommendation provided involved highly focused levels of training improve knowledge and awareness of the approach. In addition recommendations were made for on-site mentoring and coaching within the department for all stakeholder team members.

- Airside Operations

This department was the only one to score a zero for any of the 5S phases, in this case within the Environmental Sustain phase. As sustainability is vitally important to the long term success of E5S this would require reviewing with the airside operations team to clarify the key reasons for this. Overall airside operations were the 2nd lowest scoring area with a 37% score and therefore it is recommended that the whole area is reviewed thoroughly.

- Development

The E5S-SA clarified that for the Sort and Sustain phases the development department scored poorly but did reasonably well in the other three phases. Specifically within the Environmental sort phase a clear quarantine area is required for environmental wastes and this would need to be managed in an environmentally safe manner. Also any environmentally 'friendly' alternatives would need to be brainstormed, evaluated and implemented.
Within the Sustain phase negative comments were raised about the lack of E5S training therefore this would need to be remedied as highlighted in the general recommendations.
Other improvements that could be made would be the making the E5S scores clearly visible in the workplace area to all team members and to conduct reviews in an open and transparent manner.

8.6.9 Summary

The completion of this phase of the research demonstrated that the development and implementation of the E5S-SA worked effectively in a "real life" business scenario within a large corporate organisation throughout a range of different departments.

In relation to the existing 5S audit at BAA Glasgow this provided more than a simple score in that it gave results and detailed analysis of the data by each 5S phase quickly and importantly from an environmental perspective.

No significant problems were reported with the E5S-SA during either the internal and external testing/ validation of the model and there should be no reason why this approach would not work for other LSS tools and techniques once they have been tailored environmentally.

9 ELSSSA Framework Development

9.1 Introduction

The next part of the research was to develop a functional framework for the ELSSSA. This builds on the outline concept ELSSSA from the research methodology section 3.2 and uses the analysis outcomes from the Global LSS survey in section 6 and the lesson learnt from the development and testing of the pilot E5S-SA in a real life industry scenario in section 8.6.

The original ELSSSA concept depicted in Figure 3.1 outlined a 4 phase approach designed to be used either internally by appropriately trained auditors or external auditor/consultants. The original ethos of this concept will remain however additional value added elements will be incorporated to increase its effectiveness for a wider range of business scenarios which will provide more focus in specific situations.

9.2 Aims and Objectives

The ELSSSA Framework has the following aims and objectives.

- Establish the main requirements for the ELSSSA framework
- Define the scope of the framework
- Clarify the key criteria guides for the ELSSSA Framework
- Develop the functional ELSSSA Framework Structure

9.3 ELSSSA Framework Requirements

The ELSSSA framework has 5 main key requirements which it should satisfy in order to achieve the desired long term sustainability of the approach within a designated organisation. These 5 key requirements were identified using experience garnered from implementing frameworks in operational environments from various industry sectors. Implementation of structured frameworks within a business requires a degree of pragmatism and this is reflected in the selection of these requirements. In addition the lessons learnt from the previous chapters including the case study were also important points of consideration during the creation of the framework.

9.3.1 Simplicity

As the framework will be deployed to all stakeholder levels in an organisation, many of whom may not be familiar with complex project management systems, the ELSSSA framework should be both simple and clear in its deployment.

Fulfilment of this requirement will enable the ELSSSA to be installed quickly and efficiently in an organisation with minimal additional training.

9.3.2 Logicality

The ELSSSA framework should be developed in a logical sequence using a phased approach with associated milestones for the deployment team to meet. These phases would need to be supported by a robust review mechanism that covers all the relevant stakeholder levels within each department which is being assessed.

9.3.3 Flexibility

From the perspective of flexibility there are two main areas where this is a core requirement. Firstly the framework should be capable accommodating additional deployments from different departments within an organisation as the ELSSSA process grows and is embedded within an organisation.

Secondly regarding the scope of the ELSSSA Framework it needs to be applicable to as wide a range of organisation structure types, sector types and geographic locations as possible. This is discussed in more detail in section 9.4.1.

9.3.4 Stakeholder Relevance

The framework needs to appeal to all stakeholder types if the ELSSSA is to achieve the desired long term sustainability, therefore the framework needs to consider and involve all stakeholder levels to provide parity during its deployment in each organisational department. These stakeholders should include, as a minimum, operational employees, management, support functions but also depending on the nature of the deployment include suppliers, customers and communities.

9.3.5 Environmental Drivers

Consideration of the main environmental drivers clarified from the Global LSS survey also needs to be incorporated into the ELSSSA framework. The research has highlighted the high levels of personal concern that increasing levels of environmental legislation are having in organisations. In addition the framework needs to consider the drivers from external stakeholders to consider the context for products and services provided.

Other drivers that need to be considered are the pressures from external national and global competitors who are driving environmental improvements within their own businesses therefore increasing competitive their edge. Organisations are also finding the need to merge cost and waste reduction which is another environmental driver and consideration for the development of the ELSSSA framework.

9.4 ELSSSA Scope

The framework is to be developed to cover as wide a range of different business scenarios as possible, however due to certain limitations clarified during the analysis conducted in section 6 the framework may not be applicable to all businesses without further research.

9.4.1 In Scope

The ELSSSA Framework is designed to work any combination of the following factors as depicted in Figure 9.1

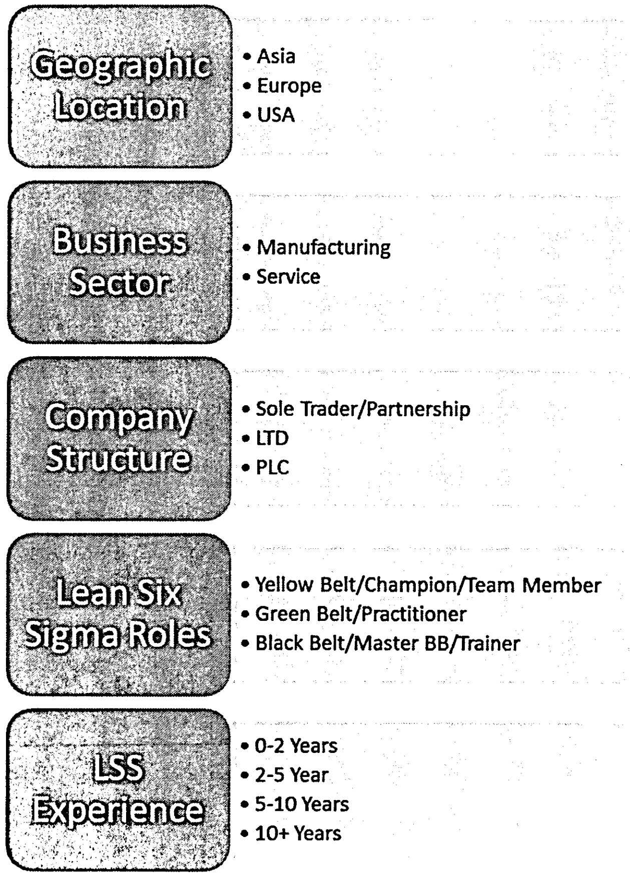


Figure 9.1: ELSSSA Framework In scope Factors

9.4.2 Out of Scope

There are a small number of exceptions that are out of the scope of the ELSSSA framework and these are mainly due to the limited responses for the Global LSS survey from certain samples. Therefore in terms of global location the framework is not truly viable for other continents such as Africa, Oceania, Central America and South America. In reality the ELSSSA framework could still be used in these geographic locations however as statistical analysis of these continents has not been performed there may be unique characteristics that have yet to be identified. Therefore these geographic locations do not fall within the guidelines depicted in Figure 9.2.

Also out of scope from the ELSSSA framework are particular company types where as previously mentioned the sample size was too small to analyse. Therefore companies that are classed as franchises and governmental structure types would not be included in the scope of the ELSSSA framework. These could still be used but would not fall within the guidelines offered in 9.5.3

9.5 Key Criteria Guides

Following the extensive Global LSS survey analysis it was possible to identify for each of the 5 key criteria and the associated questions that were cross tabulated, whether they were statistically different. The complete set of analyses in summarised in the matrix is depicted in Table 9.1. Of the 15 question types cross referenced only 2 of these do not differ statistically for all 5 key criteria questions analysed. These 2 questions (Q24 and Q25) both relate to LSS and environmental management.

Statistical Similarities and Differences Matrix - Summarised

Q5	Question	Q5 Company Location	Q7 Business Sector	Q6 Company Structure	Q11 Lean Six Sigma role	Q10 Lean Six Sigma Experience
Q7	Which Business Sector is your organisation from?	Statistically Different				
Q10	How long have you been using the Lean and/or Six Sigma approaches?	Statistically Different	Statistically the same	Statistically the same	Statistically Different	
Q15	Has Lean and or Six Sigma projects been successful in reaching the goals/expectations of your organisation?	Statistically the same	Statistically the same	Statistically the same	Statistically the same	Statistically Different
Q16	What are your the biggest concerns that you have over the deployment of Lean and/or Six Sigma within your organisation?	Statistically Different	Statistically Different	Statistically the same	Statistically the same	Statistically Different
Q18	Has the implementation of Lean and/or Six Sigma resulted in any environmental benefits within your organisation?	Statistically the same	Statistically the same	Statistically Different	Statistically the same	Statistically Different
Q20	Has the implementation of Lean and/or Six Sigma resulted in any environmental problems within your organisation?	Statistically Different	Statistically the same	Statistically the same	Statistically Different	Statistically the same
Q22	Have you heard of Environmental or Green versions of Lean and or Six Sigma, please tick those that apply?	Statistically the same	Statistically Different	Statistically Different	Statistically the same	Statistically Different
Q24	Do you consider a combined approach of Environmental Management with Lean and/or Six Sigma of value to your	Statistically the same	Statistically the same	Statistically the same	Statistically the same	Statistically the same
Q25	Do you think Lean and/or Six Sigma enhances current environmental management practices?	Statistically the same	Statistically the same	Statistically the same	Statistically the same	Statistically the same
Q26	Are you concerned about the impact of increasing environmental legislation and targets on your organisation?	Statistically the same	Statistically Different	Statistically the same	Statistically Different	Statistically Different
Q27	How much are you personally concerned about the environment?	Statistically Different	Statistically the same	Statistically the same	Statistically the same	
Q28	In general are your biggest environmental concerns, please tick all that apply?	Statistically Different	Statistically the same	Statistically Different	Statistically the same	
Q29	What is driving your organisation towards becoming "Green", please tick all those that apply?	Statistically Different	Statistically Different	Statistically the same		
Q31`	Do Lean and/or Six Sigma teams work together with Environmental employees or functions in your organisation on	Statistically Different	Statistically the same	Statistically the same		
Q33	Which of the following tools and techniques do you consider would be of value if developed into Environmental or Green	Statistically Different	Statistically Different	Statistically Different	Statistically the same	Statistically Different

Table 9.1: Global LSS Survey Analysis Summarised by Key Criteria

These characteristics from the Global LSS survey for the different types of business scenarios have been developed into the following quick reference guides that can be used by trained auditors. For example, if an auditor is analysing a company from Asia and it is from the Service sector, he/she can examine the guides to provide them with insights that may be useful. An auditor can therefore adjust their approach during the ELSSSA based on the information that can be garnered from these guides.

9.5.1 Geographic Location Guide

The geographic location guide (Figure 9.2) provides the auditor with characteristics that have been statistically demonstrated via the Global LSS survey analysis to be relevant to these particular locations. This will be useful for the auditor when they are conducting the ELSSSA approach with an organisation in these geographic locations and will provide them with hints and tips on what to examine within the organisation.

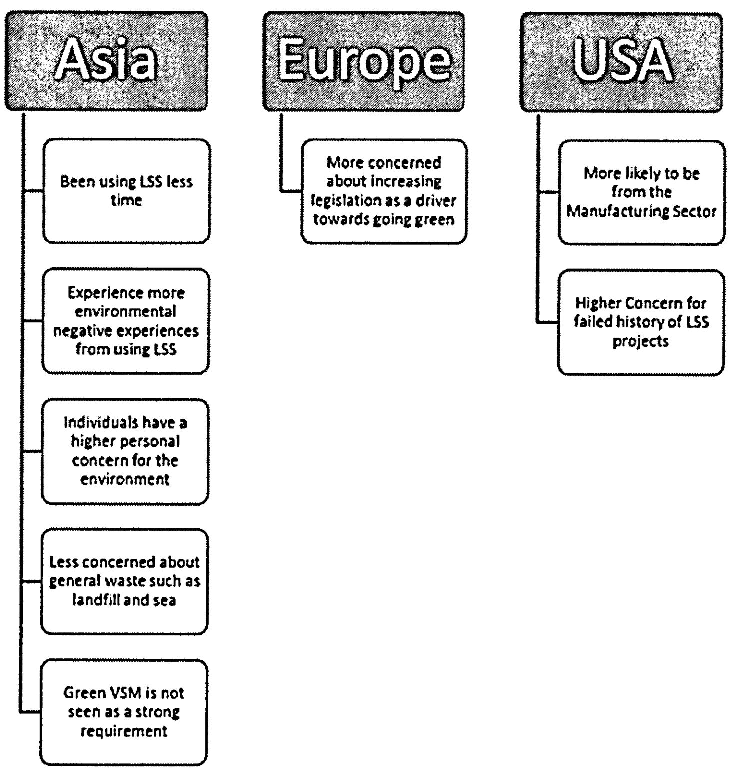


Figure 9.2: Geographic Location Guide

9.5.2 Business Sector Guide

This guide depicted in Figure 9.3 will assist the auditor in viewing the statistical differences between the manufacturing and service sectors. For example, for assessments conducted in the service sector, the auditor would be aware that this sector has a higher awareness of Green Sigma and Green Lean Six Sigma and could therefore prime them with this information when defining the project.

Alternatively the auditor could utilise the guide in manufacturing sector scenarios to be aware that there is a greater probability of a history of failed projects within the organisation and could focus efforts more on sustainability of LSS within the organisation.

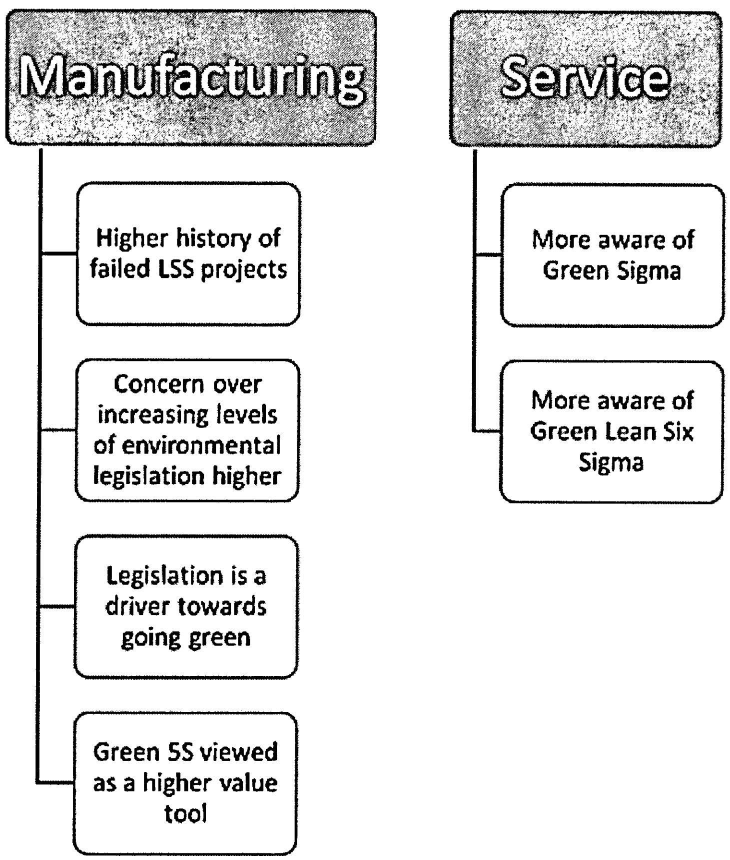


Figure 9.3: Business Sector Guide

9.5.3 Company Structure Guide

Using the company structure guide (Figure 9.4) the auditor can view the key potential differences between the various structure types that they may encounter during the auditing phase. These insights provide the auditor with relevant information about the organisational structure that is being assessed. For example, when PLC type organisations that are being audited there is an increased probability of lower awareness of Green versions of LSS. Therefore, the auditor may place more focus on the training and awareness in the form of on-site workshops to help increase this knowledge.

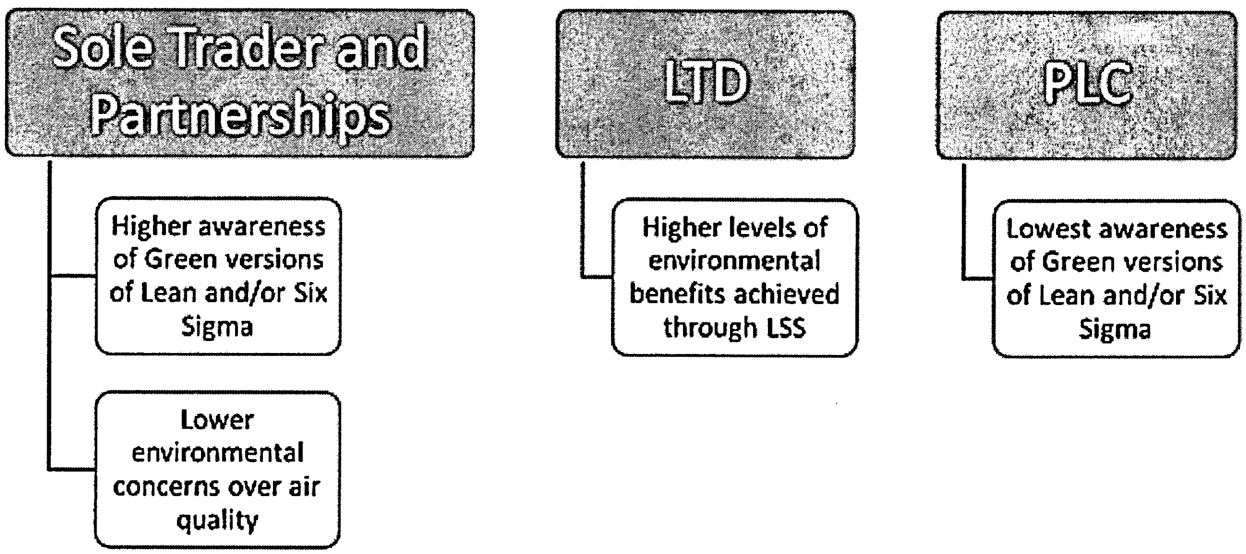


Figure 9.4: Company Structure Guide

9.5.4 LSS Role Guide

For the 3 different role type classifications a guide (Figure 9.5) has been developed that will provide valuable insights into the views each of these roles groupings analysed in Section 6.7. For example an auditor examining the characteristics of different role types in an organisation could use the guide to provide focus on the yellow belt group to understand the reasons for possible high levels of concerns over increasing levels of environmental legislation.

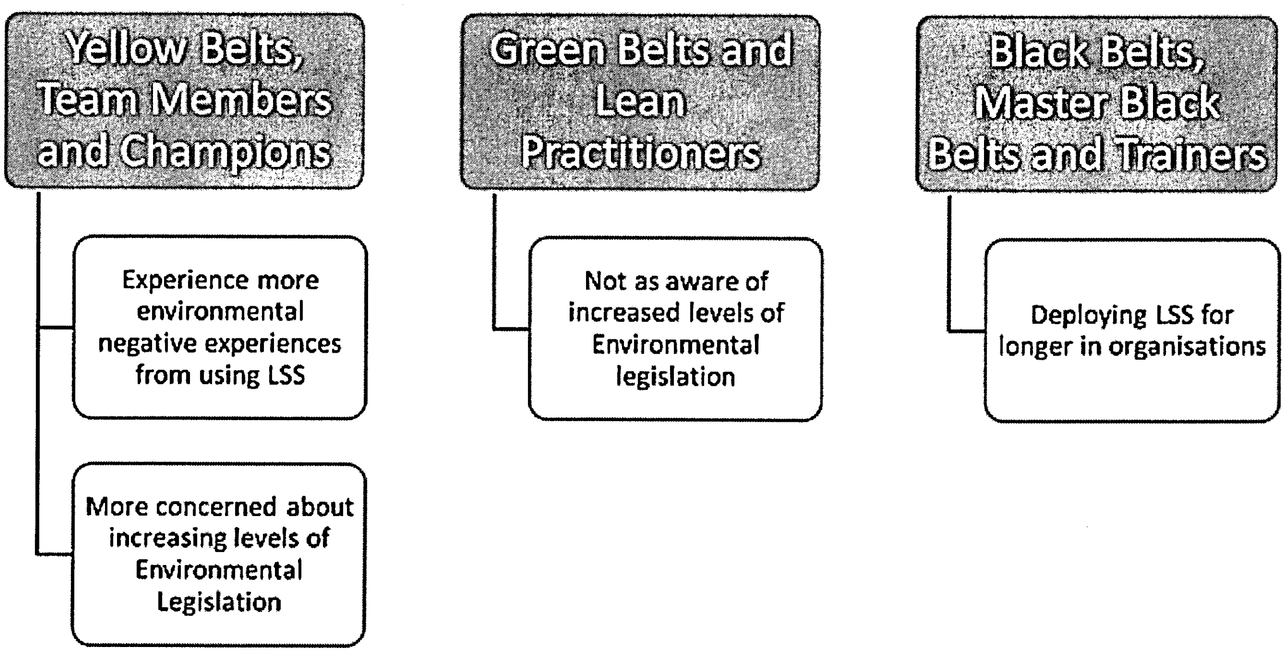


Figure 9.5: LSS Role Type Guide

9.5.5 LSS Experience Guide

The LSS experience guide (Figure 9.6) is designed to enable the auditor to identify certain characteristics that may be present in an organisation with various levels of LSS experience. For example for LSS users with 0-2 years' experience the auditor could focus on asking questions relating to the low level of knowledge of LSS in their company and the reasons for this.

In relation to more knowledgeable users with 5-10 years' experience who have experience greater levels of environmental benefits from using LSS the auditor may wish to analyse why these more practiced users have experienced this.

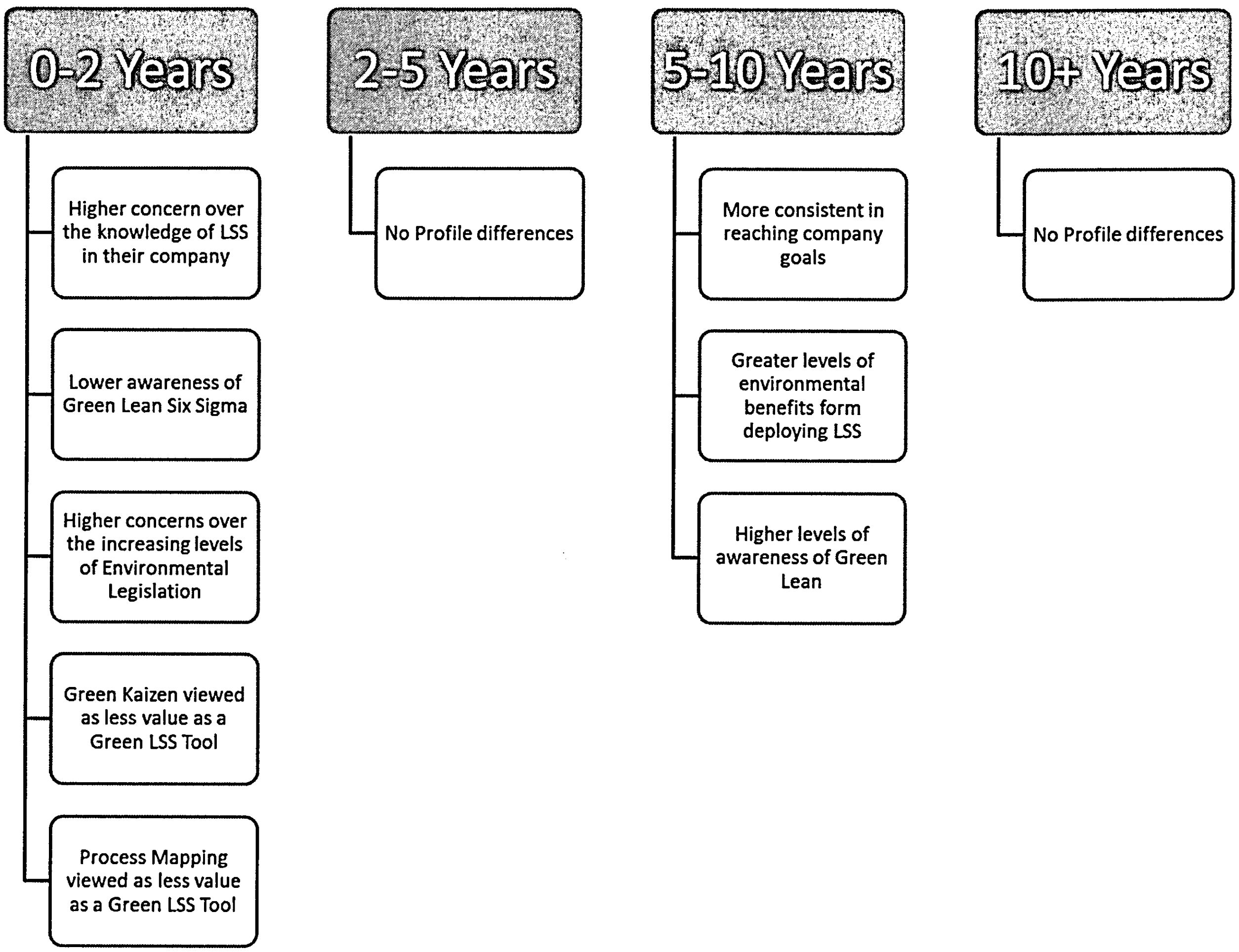


Figure 9.6: LSS Experience Guide

9.6 ELSSSA Framework Structure

Following the development of the E5S-SA, its associated case study and the knowledge garnered form the Global LSS Survey the final structure proposed for the ELSSSA framework has evolved from the original concept framework developed in Section 3.1.

The structure consists of 5 phases and the individual phases have additional steps to help enforce increased levels of sustainability of the approach within the client's organisation. The logic behind the framework development and how it was created was based on the researcher's experience of implementing operational frameworks in various industry sectors, the lessons learnt from the research conducted thus far and the ELSSSA framework requirements clarified in Section 9.3.

From an experience perspective the ELSSSA framework required a clear high level of stakeholder involvement in order to garner as much value added information as possible during the auditing process. In addition the framework needed a clear feedback mechanism to the organisation with which a clear action focused plan could be developed.

In terms of lessons learnt the ELSSSA framework needed to include adequate awareness to employees in ELSS tools and techniques. This would help facilitate improved levels of answers to audit questions.

The 5 phases for the functional ELSSSA Framework are depicted in the Figure 9.7.

Functional ELSSSA Framework

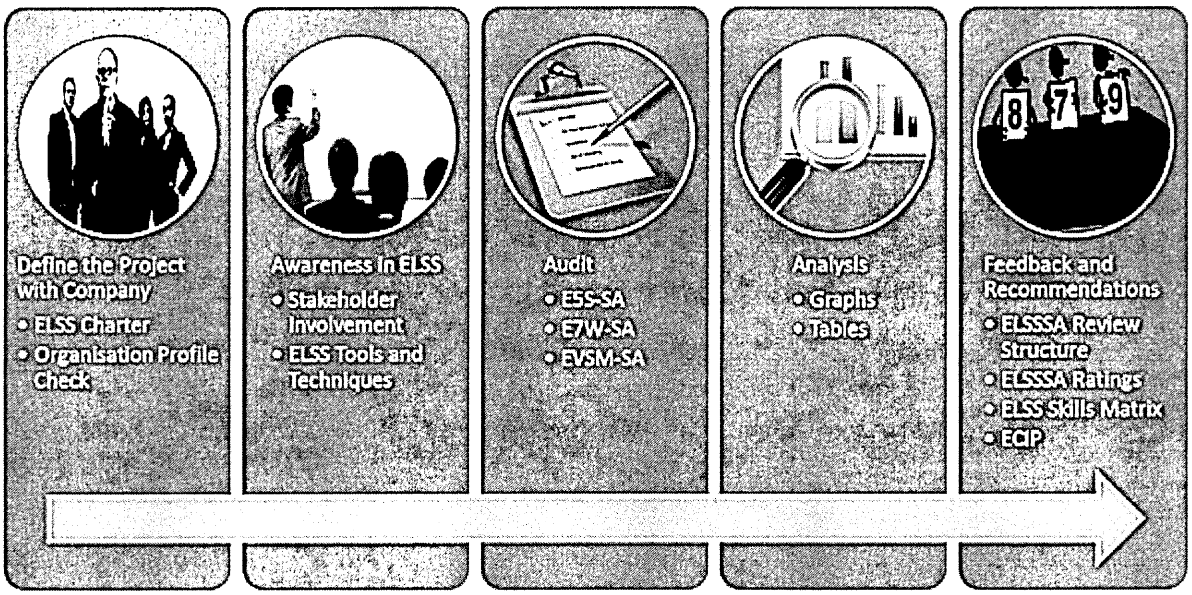


Figure 9.7: Functional ELSSSA Framework

9.6.1 Phase 1 – Define the Project

At the define stage it is proposed to involve a select number of key employees that cover all the relevant stakeholders and levels at the organisation. This stage would be conducted on-site by an external 3rd party in the 1st instance however once the 1st deployment has been completed it could in future be done internally by an appropriately qualified employee such as a LSS Master Black Belt / Black Belt.

The aim of this phase will be to garner all the relevant information required about the organisation to be assessed and to develop this into an outline plan. This phase will perform a profile check of the organisation to be assessed using a survey similar to the one developed in section 4. The survey would clarify the key characteristics of the organisation in relation to the scoping requirements. In the first instance it would identify whether the company fits within the scope of the ELSSSA method.

Secondly data from the survey and also on-site discussions with stakeholders will be used to develop an adaptation of a Project Charter called the Organisation ELSS Charter.

Organisational Survey Profile Check

The organisational survey profile check would re-use the Global LSS survey developed in Section 4 which would be issued to the key stakeholders identified from the organisation. This 1st step of the framework should be issued at the start of the project using the SNAP Software via email or on a web based site once the stakeholders have been agreed.

In parallel with this activity the Auditor should utilise the key criteria guides outlined in 9.5 to provide potential insights into the characteristics of the organisation. These insights can be used as discussion points with the clients employees to garner further knowledge and awareness of the current state.

This task provides valuable information about the organisation that is to be assessed using the ELSSSA framework. The survey would clarify at this early stage if the company is new to LSS or long established in its deployment and the levels of success achieved thus far. Also of value is that any specific concerns over the deployment of LSS would be collected by the survey. These concerns could be due to lack of management commitment to LSS, or due to the organisations lack of understanding of the LSS approach for example. The survey would also highlight if certain stakeholders did not have training and awareness in LSS, which would be an opportunity for improvement.

Environmentally the profile check would pinpoint any environmental benefits they had achieved through the use of LSS and also any negatives. In terms of awareness the survey would detect if the company has any prior knowledge of environmental versions of LSS and this prior knowledge would help at the training and awareness phase in section 9.6.2.

Gauging the stakeholder views of combining LSS and environmental management practices and the value of this is another area where the survey profile check will provide useful data to build a picture of the culture of the organisation that is going to use the ELSSSA framework.

Once the organisational survey profile check has been returned by all the respondents the results of the survey can be compared to the key criteria guides to check for similarities and differences that may exist in the company.

The final purpose of the profile check is to use elements of the output data about the company being assessed to populate parts of the ELSS Charter discussed next, including environmental legislation concerns and environmental drivers.

Organisation ELSS Charter

The ELSS Charter will aim to gather important background information that will assist on the development and implementation of a solution specific to the unique requirements of an organisation. It is envisaged that the Organisation ELSS Charter will take no more than 2 weeks to define and agree with the relevant stakeholders.

The main unique elements of the ELSS Charter are that it contains an environmental problem statement. This statement clarifies any known environmental impacts within the company and where these issues exist and wherever possible these are in quantified terms. This information will be useful for Phase 2 when training in ELSS takes place, as it will clarify the specific functions or departments that need to be included in the process. This is especially useful in large organisations where focus on the core issues is required.

Also included in the charter is any environmental legislation or drivers that the organisation already has or is likely to have in the future. Capturing these concerns now will help with the overall strategy of using the ELSS tools and techniques to reduce any environmental impacts within specific parts of the business.

In addition the ELSS Charter will identify the types of environmental benefits that are sought by the organisation and again where possible to put into quantifiable terms. These benefits could be related to the 7 wastes for example. The ELSS charter will also define and agree realistic milestones for each of the phases of the ELSSSA Framework and the commitment of time from the stakeholder team and frequent reviews.

The outline ELSS charter is depicted in Figure 9.8.

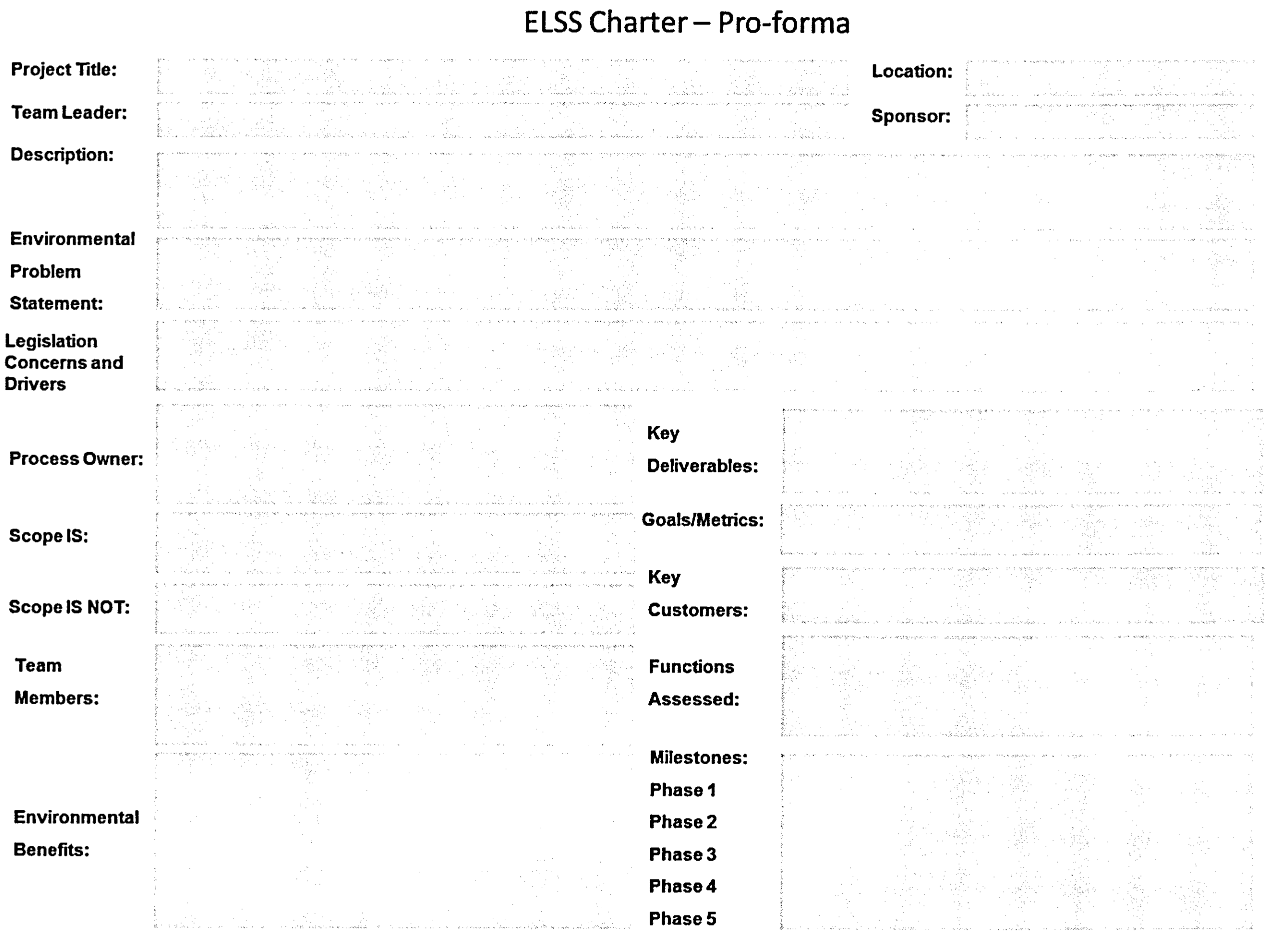


Figure 9.8: Organisation ELSS Charter Pro-forma

9.6.2 Phase 2 – Awareness in ELSS

A lesson learnt from the development and implementation of the E5S-SA at BAA Glasgow was the importance of making sure all the relevant stakeholders are provided with awareness of the environmental benefits that can be achieved from ELSS and hence this additional phase has been incorporated to the final ELSSSA Framework structure.

Using the output data from the organisational survey profile check it is possible at this stage to detect the level of knowledge of ELSS within the organisation. The results from the Global LSS survey in

Figure 5.21 show that this knowledge is highly likely to be limited at this stage however if stakeholders are aware of ELSS then this could be useful in gaining "buy-in" to the ELSSSA methodology.

At this point it is proposed that basic training would be provided to the client in ELSS demonstrating the potential environmental benefits that the approach can offer in addition to conventional LSS as outlined in the literature review section 2.3.2.

Also within the organisation profile check, information on the LSS tools and techniques utilised by the client will have been collected. Based on their current experience of LSS it is recommended initially to focus to the tools and techniques that they have awareness of and to train the organisation on environmental versions of these such as E7W, E5S and EVSM and associated case studies.

As a safeguard measure in case certain employees are not selected for this initial round of training due to extenuating circumstances e.g. employee moves department, new employee joins department, employee on leave etc. Then these employees should be identified during the audit phase in 9.6.3. In the event of this occurrence these employees would be trained in the 2nd cycle of the ELSSSA Framework.

9.6.3 Phase 3 – Sustainability Audit

The 3rd phase consists of a series of sustainability audits of the designated ELSS tools and techniques that are being deployed within the designated organisation. These would follow the same methods demonstrated for the E5S-SA at BAA Glasgow in Section 8.6 but would involve other ELSS tools well.

Therefore it is proposed that the methods for the E5S-SA using the adapted SNAP 9 Software would be developed and used across other ELSS tools required for the deployment depending upon the chosen organisations own unique requirements for specific ELSSSA tools. Potential examples of these are depicted in Figure 9.9 but could include many others which were identified to be of value by the global LSS community in the results section and Figure 5.29.

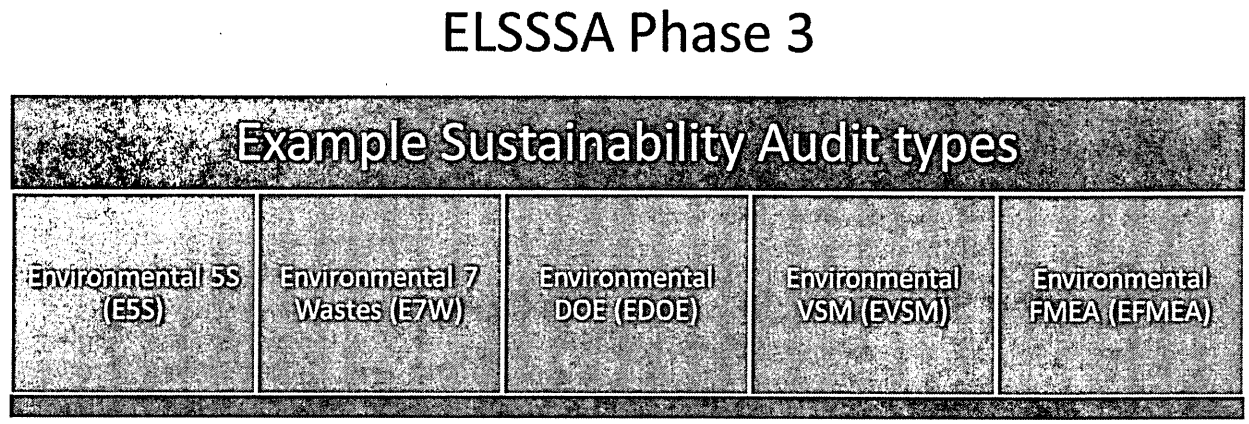


Figure 9.9: Phase 3 Example ELSSSA - Audit Types

The use of the ELSSSA for the ELSS tools and techniques can either be performed by an external 3rd party or internally by a suitably trained employee. In the 1st instance it is probably wise to have this undertaken by an external consultant or auditor to minimise any potential for bias. However, as the organisation becomes more experienced in the use of the ELSSSA Framework this could be conducted by an internal LSS Black Belt.

9.6.4 Phase 4 – Analysis

Reviewing the original concept visualised in section 3.2 for the ELSSSA, the analysis phase in this final scheme here has not changed significantly in its operation. There have been certain lessons learnt during the research and it is proposed that the analysis follows a similar path to that demonstrated by the pilot implementation at BAA Glasgow where the specially adapted off the shelf SNAP 9 software is used for each of the ELSS tools and techniques that is being assessed.

In the case study the analysis for the E5S-SA was conducted remotely by the researcher but there is no reason why this could not be conducted by either a 3rd party assessor or internal employee. However it is recommended that these individuals have a high level of understanding of LSS and its environmental benefits. Also they would need to be comfortable with the software application and would require training to understand its operation and capabilities. In reality it would probably be best for a 3rd party expert to start the process with a handover at a specific point agreed by the stakeholder team.

Regarding the Sustainability Audit delivery it could be hosted on an organisation own internal intranet and employees could access this when they need to conduct an audit or email notifications can be sent either internally or externally to the team members.

As with the case study example from BAA Glasgow, it is proposed that for each ELSS tool deployed in the organisation a score will be generated and this will be conducted for every department or function involved. This will provide each department a clear understanding of their own performance but also from a senior management perspective a set of results that can be compared and contrasted.

Using the modified SNAP 9 software graphs and tables configured to the clients own requirements would be automatically generated based on the frequency of the sustainability audits agreed without the need for an additional software package such as Excel.

9.6.5 Phase 5 – Feedback and Recommendations

Following the analysis phase, feedback should be provided to all the teams and individual stakeholders within the organisation. This feedback of the ELSSSA should be carried by either the nominated 3rd party assessor or internal employee. In addition to the feedback, detailed recommendations should also be conducted based the analysis information extracted from the software tool. Specifically this will identify, for each ELSS tool assessed, the key areas for improvement within each department or function.

Sustainability is a key requirement for this approach, consequently feedback and recommendations will be structured using the following key elements depicted in Figure 9.10 to maximise the benefits and increase sustainability/continuous improvement.

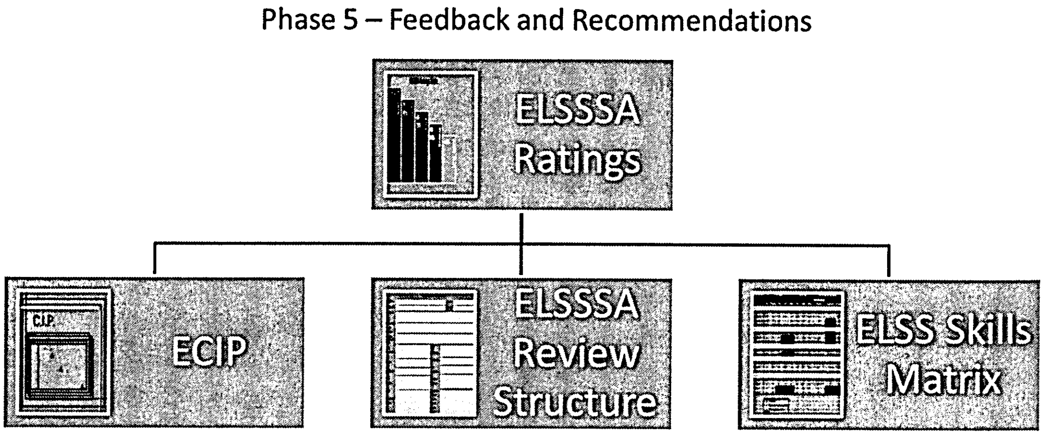


Figure 9.10: Phase 5 - Feedback and Recommendations Structure

ELSSSA Ratings

The scoring will provide a direct indicator of the performance being achieved by each department overall and individually by each ELSS tool that is being deployed. This will demonstrate progress in terms of improvement and specific areas where improvements can still be made. For each ELSSSA a score out of 100 will be generated and will be fed back to the management and department team members.

A simple ratings scale (Figure 9.11) will also give a focus for each department and this could be integrated into an organisations rewards and recognition process if they have one or be a catalyst for starting one again to assist in the sustainability of the ELSSSA approach. The ratings which use a range of precious metals in order of intrinsic value (Reed 2009) were influenced by other ratings scaled used by the researcher whilst working in industry. These types of scale provide the stakeholders within the business being assessed, an understanding of where they currently are and provides them with an aspiration and/or goal to aim for

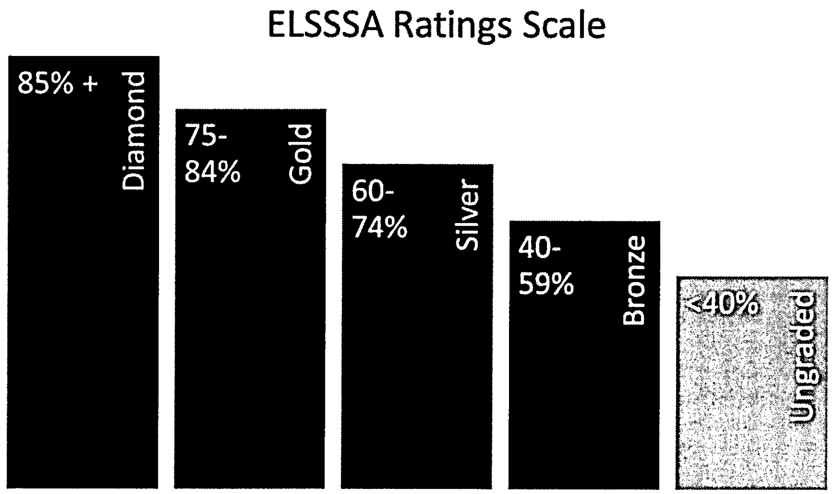


Figure 9.11: ELSSSA Rating Scale

The ratings for each designated department should be installed in a highly visible part of the workplace assessed along with a chart showing this progress weekly and these can form part of the review structure.

Environmental Continuous Improvement Plan (ECIP)

For each department that has used the ELSSSA approach and has an overall rating, it is advised that an ECIP is developed. This will take the opportunities raised by the ELSSSA analysis and embody these into a time-bound plan.

The ECIP would clarify the tasks that are required along with realistic time scales and process owners who would be attend the relevant reviews clarified in the review structure below. Also included in the ECIP would be any additional training requirements highlighted by the ELSS skills matrix.

ELSSSA Review Structure

Now that a current state has been established for all the departments involved relating to how they have performed in line with the ELSSSA, the next step is to define and configure a robust review structure to uphold sustainability. This should involve all the departments that have been assessed during the previous phase of the approach.

The review structure will require an overall sponsor usually someone senior within the organisation such as a director or CEO. This will demonstrate company buy-in to the ELSSSA approach to all the other team members.

Reviews of the ELSSSA are proposed to be in the following formats and would commence during the 2nd cycle defined in the next steps in section 9.8.

1. **ELSSSA Management Review**

- A senior management review of the ELSSSA for each of the chosen departments would allow a forum for senior management to review all the designated ELSSSA deployments together.
- This type of review would occur monthly and would allow the senior management to review the performance of each area and to make management decisions on matters such as major environmental concerns, employee training, knowledge transfer and benchmarking.

2. **Department Based Boardwalk**

- It is envisaged that weekly or fortnightly boardwalks are undertaken with the project sponsor leading the event which should be conducted in the area that is being assessed using the ELSSSA process.
- This will provide an opportunity for team members to discuss the ELSSSA "hands on" and clarify current progress, any environmental potential issues or opportunities to improve within the department. This is aimed to be an open forum for team members to discuss matters with Senior Management and focuses on bringing the upper and lower hierarchy levels together.

3. **Operational Meeting**

- An operational meeting is also advised which would involve operational team members only including LSS employees (Black, Green and Yellow Belts), environmental representatives, and operational employees.

- General progress using the feedback data from the ELSSSA analysis software tool should be reviewed in this session.
- This provides an opportunity for non-executive employees to discuss potential issues such as management commitment and leadership.
- Normally this meeting should be set for a weekly slot.

ELSS Skills Matrix

The analysis phase will have clarified any shortfalls that the organisation may have regarding skills and knowledge. These shortfalls need to be acted upon to increase sustainability of the ELSSSA approach therefore a skills matrix needs to be created that covers all the departments taking part.

The ELSS Skills matrix would need to include all the relevant ELSS methods being used by the organisation along with any supporting training that will help embody the ELSSSA approach in the organisation. This could include awareness training in environmental management such as ISO 14001 and also traditional LSS tools and techniques.

Within the skills matrix there should be clarification of the current state in terms of training status. Therefore it should state whether personnel have being trained in the designated skill and/or tools defined within the matrix. If the employee has not been trained it should clarify whether this training is required either urgently (in the short term), required in the medium to long term or not at all. This should be linked to the Personal Development Plan (PDP) of the individual concerned to ensure milestones are completed. A concept example of an ELSS skills matrix is depicted in Figure 9.12.

	LSS Skills					ELSS Tools			Environmental Awareness		
Department	5S	7 Wastes	VSM	SPC	FMEA	E5S	E7W	EVSM	Basic Aspects & Impacts	Legislation	ISO 14001
Manufacturing											
Employee 1	O	O	O	O	O	O	X	O	O	O	U
Employee 2	O	O	O	O	O	O	X	O	O	O	U
Employee 3	O	O	O	U	X	O	X	U	O		U
Employee 4	O	O	O	U	X	O	X	O	O		U
Sales											
Employee 1	X	X	X	X	X	O	O	O	O		O
Employee 2	O	O	X			O	O	O	O		O
Employee 3	O	O	X			O	O	O	O		O
Development											
Employee 1	O	O	O	O	O	O	O	O	O	O	U
Employee 2	O	O	O			O	O	O	O	O	U
Quality											
Employee 1	O	O	O	O	O	U	U	U	X	X	O
Employee 2	O	O	X	O	X	U	U	U	X	X	O
Employee 3	X	X	O	X	O	U	U	U	X	X	O
Management											
Employee 1	O	O	O	O	O	O	O	O	X	U	O
Employee 2	O	X	X	X	X	O	O	X	X	U	O
Employee 3	X	X				O	O	X	X		
Employee 4	X	X				X	X	X	X		

O	Trained
U	Training required urgently
X	Training Required
	Not required

Figure 9.12: Example ELSS Skills Matrix

The skills matrix should be installed in the workplace where the ELSSSA approach is being deployed operationally and a team member needs to be in charge of reviewing this against the agreed timescales on the ECIP. Formally it is advised that the ELSS skills matrix is reviewed at each boardwalk session clarified in the review mechanism.

9.7 Gate Reviews

It is proposed at the end of each of the phases of the ELSSSA framework to hold a gate review to ensure that each of the tasks that are required are completed before the stakeholder team can continue to the next phase.

Below is an example pro-forma of the typical deliverables that are required to be completed for each of the individual phases to ensure that no important steps are missed.

Phase No	Deliverable	Comments	Status
1	Initial stakeholder team clarified		
1	Outline project identified		
1	Environmental problem Statement agreed		
1	Legislation concerns and drivers identified		
1	Scope of project agreed		
1	Formal ELSS Charter created		
1	Organisational Profile Check Issued		
1	Organisational Profile Check reviewed		
2	Full Stakeholders Involvement		
2	Appropriate ELSS Tools and Techniques selected		
2	Team members identified for training		
2	Training in ELSS Tools and techniques provided		
3	Auditors identified and agreed		
3	Auditing conducted at regular frequencies		
4	Analysis of Audit returns		
4	Audit scores generated by department		
4	Graphs and tables generated and in the workplace		
5	ELSSSA Review structure formulated and operational		
5	ELSSSA Ratings provided and in workplace		
5	ELSS Skills Matrix developed		
5	ECIP in place		

Figure 9.13: Pro-forma for Gate review Deliverables

9.8 Sustainability Cycle

Following the completion of the phase 5 of the approach it is the intension to restart the ELSSSA from the beginning, deemed here as the Sustainability cycle. Sustainability is a key element to the long term success of the ELSSSA approach therefore a continuous improvement cycle is required.

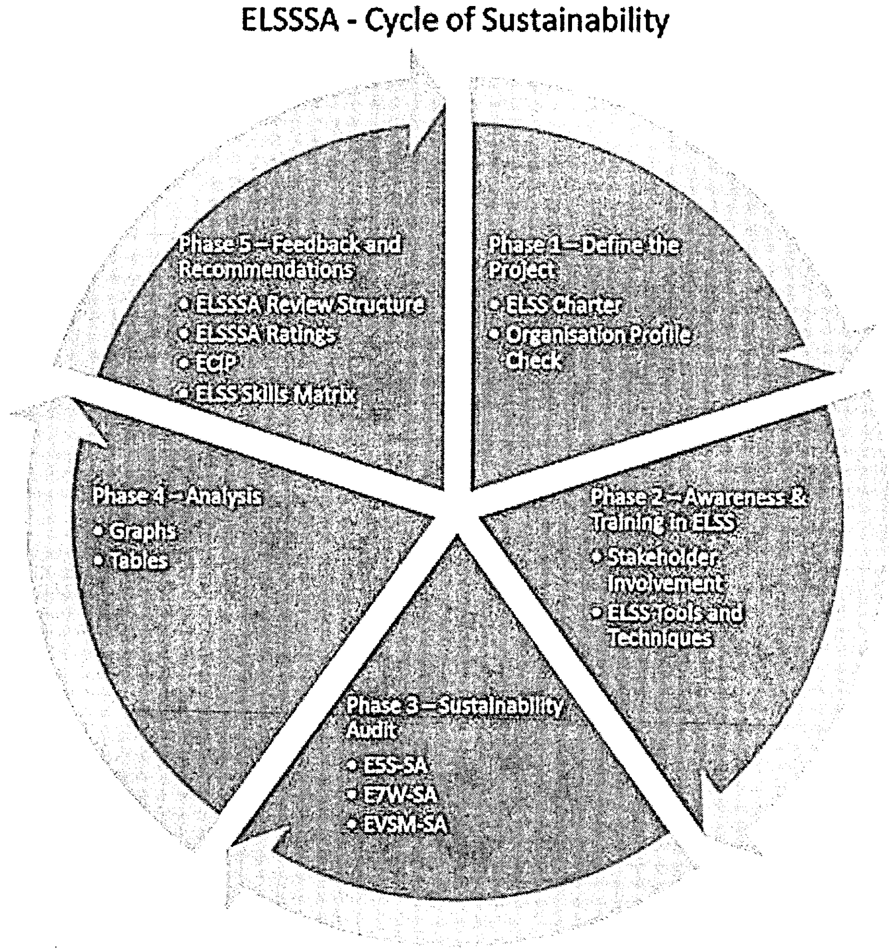


Figure 9.14: ELSS Cycle of Sustainability

At the start of the 2nd cycle the aim is to develop individual ELSS Charters for each individual department that is being assessed using the ELSSSA framework. Information from the feedback and recommendations is to be utilised to develop the individual ELSS Charters for each individual area that is being assessed. The pro-forma in Figure 9.8 can be re-used for this task.

The completed departmental ELSS charter should be placed in a highly visible workplace area in the department preferably alongside the ECIP and Audit scores. This will provide a hub for discussion during the review structures weekly boardwalk meetings.

9.9 Next Steps

Following the development and integration of the ELSSSA Framework, the next and final chapter will conclude the main elements of the research conducted and clarify the contribution to knowledge that has been provided. In addition recommendations will be clarified by the researcher for potential further research in the future

10 Conclusions and Recommendations

10.1 Introduction

In this final section the research conclusions are stated, the originality of the thesis and contribution to knowledge are described and recommendations for further work are provided.

10.2 Research Conclusions

The conclusions of the research have been divided into the results/analysis of the Global LSS Survey and the development, testing and case study of the ELSSSA tool and the resulting framework that complements it.

10.2.1 Global Survey Results and Analysis

The survey result and analysis provided many useful conclusions that were crucial to the development of the associated ELSSSA tool and framework.

- Conventional LSS is most popular (in descending order) in the USA, Europe and Asia, whilst deployment of the approach in the regions of Oceana, Africa and South/Central America is still very limited.
- As a business improvement approach LSS is most widely deployed in PLC organizational structure types followed by LTD companies.
- Knowledge and awareness of Green versions of Lean and/or Six Sigma is growing with "Green Lean" being the mostly widely known but the approach is still in its infancy and knowledge and awareness of "Green" versions of LSS is lowest in PLC structure types.
- Manufacturing is the most frequently reported industry sector type overall and in the USA to use LSS, however within Europe and Asia it is split equally across the manufacturing and service sectors.

- This research discovered that the biggest concerns of the LSS community were the lack of management commitment and the long term sustainability of the approach within their organisations.
- Geographically, organisations deploying LSS in the USA had higher concerns over the history of failed projects than their counterparts in Europe and Asia, whilst in Europe the concern was higher over the increasing levels of environmental legislation on their businesses.
- The majority of LSS users report environmental benefits from their projects with reduced energy consumption being the biggest type of benefit to their business and in addition LSS users report that instances of environmental negatives from deploying LSS are in the main, rare.
- The LSS Community strongly believes that the combined use of LSS and environmental management practices is of value to their organisations and they are highly concerned about the impact of increasing legislation.

10.2.2 ELSSSA Tool and Framework

The following conclusions are stated based upon the experience and knowledge garnered from the ELSSSA tool and framework: -

- The outcome of the ELSSSA evaluation deemed 5S to be the most suitable LSS tool to be developed into an ELSS Audit tool.
- It is feasible and viable to develop and apply E5S in a "real life" deployment scenario
- The awareness and demonstration of the E5S-SA concept garnered positive feedback from industry and academia.
- It is feasible and viable to develop an E5S-SA tool that is both reliable and robust as demonstrated during the internal and external testing and validation with the BAA Glasgow.

- In comparison to conventional 5S Audits, the E5S-SA provided the client with quick and detailed analysis of each of the E5S phases, whilst also focusing on the key environmental impacts
- The E5S-SA provided the client with detailed feedback and recommendations that could be focused on the key problem areas within any of its business functions chosen for the deployment.
- The E5S-SA tool demonstrated that this audit methodology could be developed further for other types of LSS tools.
- It is feasible and viable to develop a structured ELSSSA framework that can be applied across different geographic locations, company structure types and industry sectors.
- تعدد The key criteria guidelines developed for the ELSSSA Framework provides its users with a wide range of strategies that can be deployed, depending on the given situation at the organisation being assessed.
- It is feasible and viable to develop an organisation profile check and ELSS project charter that aids the clarification of the current state of a company's unique key characteristics.
- A systematic 5 Phase approach for the ELSSSA Framework allows organisations to minimize problems through the use of structured gate reviews.
- The development of a closed loop "sustainability cycle" provides a long term continuous improvement process for the ELSSSA framework that can be coordinated and owned by each organizational function.

10.3 Contribution to Knowledge

The research conducted that has been included within this thesis provides the following original contributions to knowledge:

- The results of the Global survey demonstrate the knowledge and awareness of environmental versions of LSS and the potential environmental benefits that can be achieved through its deployment.
- The statistical analysis of the Global LSS survey provides unique insights and awareness concerning the similarities and differences of certain key characteristics of the Global LSS community.
- The development, testing and application in a "real life industry scenario" of the E5S-SA software tool contributes to providing organisations with practical results and diagnostics which can be quickly developed into structured feedback and recommendations.
- The development of an operational ELSSSA framework contributes to a methodology that can be applied in a range of geographic locations (USA, Europe and Asia), and in addition Manufacturing and Service industry sectors and a variety of organizational structure types.

Critical analysis using the SWOT technique (Dosher et al 1960) as depicted in Figure 10.1 below shows what is considered to be the strengths, weaknesses, opportunities and threats of the research study that has been conducted.

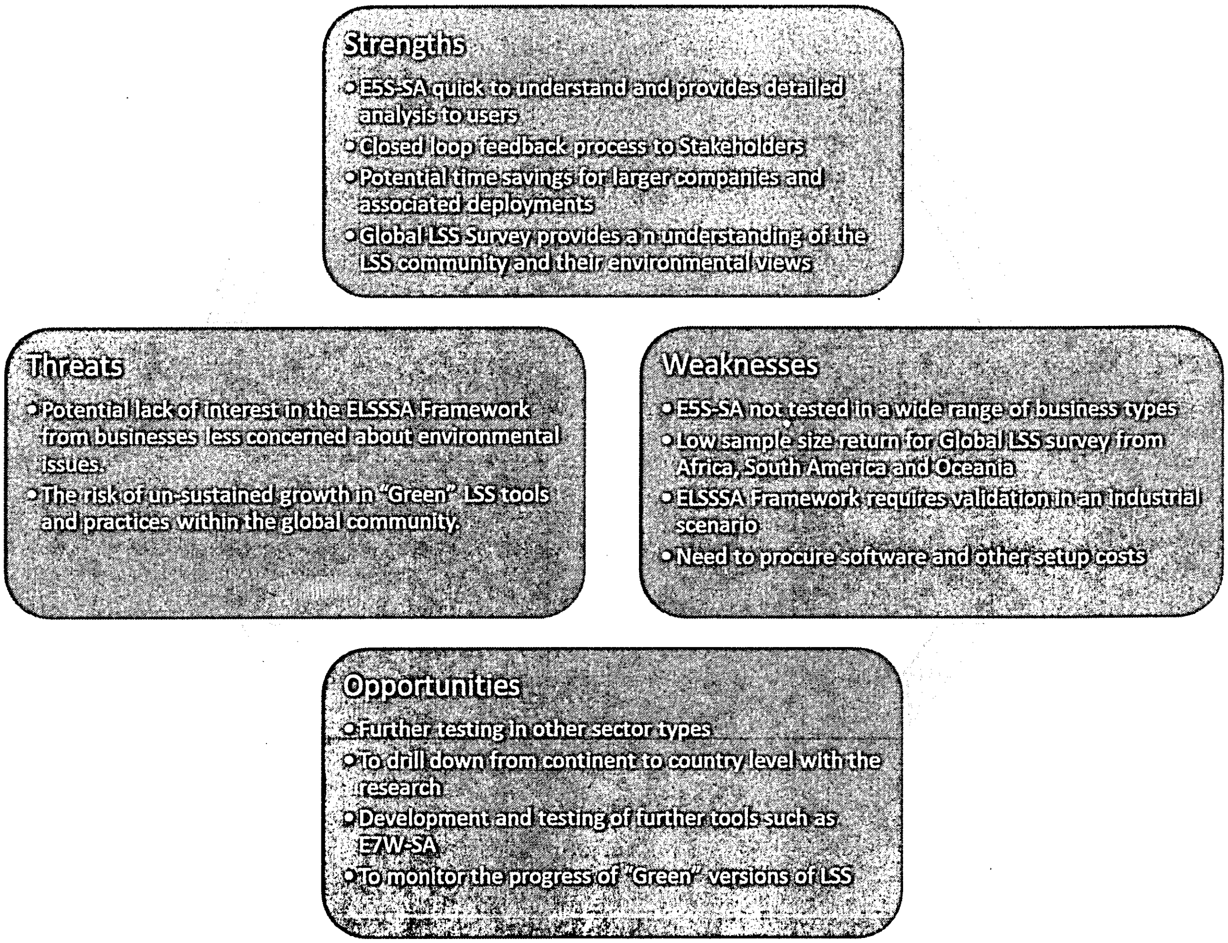


Figure 10.1: SWOT Analysis of the Research Conducted

The strengths of the research have been discussed in details in the conclusions and contrition to knowledge sections however it is worth also considering a comparison of the E5S-SA in with conventional 5S auditing methods used commonly in industry. It can be stated that the new methodology has a number of advantages. The research has demonstrated that the E5S-SA provides an organisation with focused results and detailed analysis whilst simultaneously doing this in a quick manner. This will be of particular help for organisations who are implementing 5S in a number of departments which involve a high number of employees. The outcome of this will be large time savings due to the closed loop feedback within the E5S-SA method in comparison with the open loop of conventional 5S auditing methods. This time saving will in addition provide cost reductions in performing the 5S audits, the impact of this will increase with the larger 5S deployments.

In relation to traditional 5S auditing the E5S-SA approach will also provide an additional element of the environmental perspective to 5S. This will be of particular interest to organisations wishing to assess and improve their own environmental awareness and performance using 5S in a quick and easy manner.

The main weaknesses of the research are that the ELSSSA tool was tested in a single industry sector and this transcends into the potential opportunity for further research and testing of the E5S-SA to garner further feedback and information. Also even though the sample size return for the Global LSS survey was high there were certain regions where the sample was too small to conduct detailed analysis and additional research in these areas could be useful to gain further understanding of the similarities and unique nuances that may exist.

In addition the ELSSSA Framework has not been extensively tested and this would be useful to fully understand any potential issues and problems that could exist. Finally some organisations may baulk at the prospect of investing in the costs of software to run the ELSSSA, however this is probably more applicable to very small businesses.

In terms of threats that may exist, there will be organisations that may not be concerned about the environment and the potential impacts and therefore this type of approach would not be of interest. However the Global LSS demonstrated that the majority is concerned about the environment and they see the value in combining LSS with Environmental Management practices. An additional risk is that the increasing interest in "Green" LSS tools and techniques could be short lived and that something else may come along that becomes the new "flavor of the month"

For instances where there are clear opportunities for the research, these will be considered within the recommendations discussed in section 10.4.

10.4 Recommendations for Further Work

The research has provided a number of outcomes and solutions to specific problems faced by global organisations regarding LSS and/or Environmental Management Practices and, in addition, it has also provided insights into specific areas where further research is required.

Further development of the Global LSS Survey would provide more focused analysis which could be incorporated into the ELSSSA framework guidelines developed in section 9. For example an enhanced survey could drill down to more specific geographic locations (countries rather than continents) and clarify the potential unique differences between say the UK, France and Germany. This would increase the usability of the framework and also help us understand the nuances that may exist between different countries'. However, the survey would require a suitable sample size for each individual country included in the statistical analysis.

In addition if the sample size could be increased sufficiently additional research could be conducted on more specific industry sectors rather than the manufacturing and service sectors analysed in this thesis. This additional data would provide a more sector specific development of the ELSSSA framework thus providing more relevant insights and guidelines for both the auditor and the key stakeholders within the chosen organisation.

The Global LSS survey also indicated that in manufacturing there was a greater probability of a failed LSS project than in the service sector and more research is required in this area to understand why this occurs. Identifying the reasons why the service sector is more successful could provide methods to reduce the risk of failure in manufacturing organisations.

The development of the E5S-SA and associated case study in section 8 demonstrated the potential benefits from deploying such a methodology and further work is required to develop and test this methodology for other LSS tools and techniques that were identified of value by the Global LSS community via the survey. It is proposed that the development of tools such as the E7W-SA and

EVSM-SA would build into a suite that could be called on and deployed as part of the ELSSSA Framework.

The implementation of the E5S-SA has thus far been deployed in the transportation sector only and additional implementation is required in other business sectors to further develop and refine the product to ensure its capabilities.

The research has focused on the development of an ELSSSA framework. However, it could also be developed for non-environmental purposes as a LSSSA framework for companies disinterested in garnering the potential environmental benefits. For some organisations who are new to LSS it may be “too much too soon” to dive into the deployment of ELSSSA however the deployment and use of a LSSSA Framework which could be adapted later on into a ELSSSA framework may be more agreeable to some organisations.

General awareness of “green” versions of Lean and /or Six Sigma is in its infancy. Further work to monitor its progress would allow us to understand if these new approaches and methods are the future of LSS or a passing phase that may not be sustained. .

The continued development of combining LSS and environmental practices into a formalized framework such as the ELSSSA needs “buy in” and development from larger organisations such as professional or governmental institutions in order to gain the traction required for widespread deployment. This would provide significant environmental benefits in addition to the traditional QCD improvements. This would apply to SME sized organisations in particular that may not have the infrastructure to develop the ELSSSA Framework.

As it currently stands, it would appear that industry and governments are missing out by failing to exploit the potential benefits that can be achieved through the combination of LSS and Environmental Management Practices.

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Appendix A: Global LSS Survey

Sheffield Hallam University
SHARPENS YOUR THINKING

Research Questionnaire

"Exploration of Lean Six Sigma and Environmental practices within organisations"

Note this questionnaire is anonymous and the data is to be used as part of PhD research

Please complete the following questionnaire for your department or function. Your time is appreciated.

The questionnaire will take around 5-10 minutes to complete

The questionnaire has been developed to be completed by employees who have prior knowledge and experience (basic-advanced level) of Lean and/or Six Sigma

If you have any problems please contact James Marsh Tel: 0780 6505859 or Email: jamarsh8@my.shu.ac.uk

Figure A.1: LSS Survey Introduction

Background Information

Q1 **Gender**

--Click Here--
- *Male*
- *Female*

Q2 **What is your age?**

--Click Here--
- *Under 18*
- *18 to 25*
- *26 to 35*
- *36 to 45*
- *46 to 55*
- *56 to 65+*

Q3 **Length of Company Service**

--Click Here--
- *up to 1 Year*
- *1-3 years*
- *4-5 years*
- *6-10 years*
- *11 years +*

Q4 **Organisation Level**

--Click Here--
- *Support Staff*
- *Operational employee*
- *Supervisor*
- *Team Leader*
- *Manager*
- *Director*

Figure A.2: LSS Survey Background Information

Organisation Profile

Q5 Company Location

--Click Here--

- *Africa*
- *Asia*
- *Central America*
- *Europe*
- *North America*
- *Oceania*
- *South America*

Q6 Type of Business

--Click Here--

- *Sole trader*
- *Partnership*
- *Limited*
- *Public Limited Company*
- *Franchise*
- *Governmental*

Q7 Which Business Sector is your organisation from?

--Click Here--

- *Agriculture*
- *Aerospace*
- *Automotive*
- *Banking and Finance*
- *Business Consultancy*
- *Computing*
- *Design*
- *Domestic services*
- *Education*
- *Electronics*
- *Energy*
- *Entertainment*
- *Environment*
- *Food*
- *Government and Politics*
- *Healthcare*
- *Law and Legislation*
- *Logistics and Supply Chain*
- *Manufacturing*
- *Property and Building*
- *Retail*
- *Textiles*
- *Telecomms*
- *Technical Services*
- *Transport and Travel*
- *Other*

Figure A.3: LSS Survey Organisational Profile

Q8 Department / Function you work in?

--Click Here--

Administration
Customer Services
Design
Engineering
Finance
Human Resources
IT
Logistics / Supply Chain
Maintenance
Management
Procurement / Purchasing
Production / Operations
Quality / Continuous Improvement
Research and Development
Sales and Marketing
Shipping / Warehousing
Training and Education
Other

Figure A.4: LSS Survey Organisational Profile

General Lean Sigma Questions

Q9 Have you had formal training in Lean and/or Six Sigma?

--Click Here--

- *Lean*
- *Six Sigma*
- *Lean Six Sigma*
- *None*

Q10 How long have you been using the Lean and/or Six Sigma approaches?

--Click Here--

- *I have never used Lean and/or Six Sigma*
- *6 Months or less*
- *7-12 Months*
- *1-2 Years*
- *2-5 Years*
- *5-10 Years*
- *10 Years +*

Q11 Your Lean and or Six Sigma Role

--Click Here--

- *Team member*
- *Trainer*
- *Practitioner*
- *Yellow Belt*
- *Green Belt*
- *Black Belt*
- *Master Black Belt*
- *Champion*
- *No Role*

Figure A.5: LSS Survey - Lean Six Sigma Questions

Q12 Which Lean and/or Six Sigma Tools and techniques do you use, please tick those that apply?

7 Wastes ☐	*Pareto Analysis* ☐
5S ☐	*Project charter* ☐
5 Whys ☐	*Process Mapping* ☐
ANOVA methods ☐	*OEE* ☐
Brainstorming techniques ☐	*QFD* ☐
Change management ☐	*Simulation* ☐
DOE ☐	*SIPOC* ☐
DFSS ☐	*SMED / Quick Changeover* ☐
Environmental analysis ☐	*SPC / Control Charting* ☐
FMEA ☐	*Statistical Software (e.g. MINITAB, SPSS)* ☐
Fishbone diagrams ☐	*TPM* ☐
Histograms ☐	*TRIZ* ☐
Gauge R&R ☐	*Value stream Mapping (VSM)* ☐
GLOBAL 8D ☐	*Visual Controls* ☐
KANBAN / Line Balancing ☐	*VOC (Voice of the customer)* ☐
Poke Yoke / mistake proofing ☐	

Figure A.6: LSS Survey – Lean Six Sigma Questions

Q13 What type of benefits have you acheived from using Lean and/or Six Sigma, please tick those that apply?

- *Improved quality (e.g less defects, less variation)*
- *Lower costs (e.g.quantified reductions or benefits to the business)*
- *Improved delivery (e.g customer lead-times reduced)*
- *Cultural benefits (e.g. more motivated workforce)*
- *Other*

Q14 If other to question 13 please specify the benefits

Q15 Has Lean and or Six Sigma projects been successful in reaching the goals/expectations of your organisation?

	Alwa ys	*Most ly*	*Half the time*	*Rarel y*	*Neve r*	*not sure*
Please select an option						

Q16 What are your the biggest concerns that you have over the deployment of Lean and/or Six Sigma within your organisation?

- *Long term Sustainability of the approach*
- *Management Commitment*
- *Complexity of the Approach and tools/techniques*
- *Motivation of the team*
- *Teams overall understanding of Lean and/or Six Sigma*
- *Quality of the training provided*
- *Lean Six Sigma not applicable to your business sector*
- *Negotivity from team members*
- *Negotivity from non-team members*
- *Unrealistic Target & Goals*
- *Not all the correct stakeholders involved*
- *Previous history of failed improvement projects*
- *Your own belief in the capability of Lean and/or Six Sigma*
- *I have no concerns*
- *Other*

Q17 If other please specify your individual concerns

Figure A.7: LSS Survey - Lean Six Sigma Questions

Environmental Questions

Q18 Has the implementation of Lean and/or Six Sigma resulted in any environmental benefits within your organisation?

	Always	*Mostly*	*Half the time*	*Rarely*	*Never*	*Don't know*
Please select an option	○	○	○	○	○	○

Q19 If so please provide examples

Q20 Has the implementation of Lean and/or Six Sigma resulted in any environmental problems within your organisation?

	Always	*Mostly*	*Half the time*	*Rarely*	*Never*	*Don't know*
Please select an option	○	○	○	○	○	○

Q21 If so please provide examples

Figure A.8: LSS Survey Environmental Questions

Q22 Have you heard of Environmental or Green versions of Lean and or Six Sigma, please tick those that apply?

- *Green Lean* ☐
- *Green Sigma* ☐
- *Green Lean Six Sigma* ☐
- *None of the above* ☐
- *Other, please specify* ☐

Q23 If other to question 22 please specify in more detail

Q24 Do you consider a combined approach of Environmental Management with Lean and/or Six Sigma of value to your organisation?

- *Yes* ○
- *No* ○
- *Not considered this before* ○

Q25 Do you think Lean and/or Six Sigma enhances current environmental management practices?

- *Yes* ○
- *No* ○
- *Not considered this before* ○

Q26 Are you concerned about the impact of increasing environmental legislation and targets on your organisation?

- *Yes* ○
- *No* ○
- *Not considered this before* ○

Figure A.9: LSS Survey Environmental Questions

Q27 How much are you personally concerned about the environment?

	Extremely	*Highly*	*Sometimes*	*Slightly*	*Never*
Please select an option					

Q28 In general are your biggest environmental concerns, please tick all that apply?

- *Air quality (emissions from transport, power stations)*
- *Energy production (conventional methods)*
- *Food contamination*
- *General health of people, plants and wildlife*
- *Global warming*
- *Packaging (production, recycling and disposal)*
- *Transportation methods (air, sea and land)*
- *Water quality*
- *General waste (landfill, sea)*
- *Other*

Q29 What is driving your organisation towards becoming "Green", please tick all those that apply?

- *Legislation (e.g local, national and/or global)*
- *Customers (e.g more aware of the environment)*
- *Economic demands (e.g raw materials, logistics, waste disposal)*
- *Competitors (e.g they are acting on green issues within your sector)*
- *New opportunities (e.g. awareness of the environment provides need for new products and services)*
- *Other reasons*

Q30 If other to question 29 please explain

Q31 Do Lean and/or Six Sigma teams work together with Environmental employees or functions in your organisation on business improvement projects?

- *Yes*
- *No*
- *Not sure*

Q32 If no to question 31 please specify why this may not happen

Figure A.10: LSS Survey Environmental Questions

Q33 Which of the following tools and techniques do you consider would be of value if developed into Environmental or Green Lean Six Sigma tools and techniques, please tick all that apply?

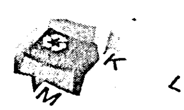
7 Wastes ☐	*Pareto Analysis* ☐	*SPC / Control Charting* ☐
5S ☐	*Project charter* ☐	*TPM* ☐
DOE (Design of Experiments) ☐	*Process Mapping* ☐	*Value stream Mapping (VSM)* ☐
DFSS ☐	*OEE* ☐	*Visual Controls* ☐
FMEA ☐	*QFD* ☐	*VOC (Voice of the customer)* ☐
Fishbone diagrams ☐	*Simulation* ☐	*Other (please specify below)* ☐
GLOBAL 8D ☐	*SIPOC* ☐	
Kaizen ☐	*SMED / Quick Changeover* ☐	
Poke Yoke / mistake proofing ☐		

Q34 If other to question 32 please describe.

Q35 If you are interested in receiving feedback or being involved in the research, please leave your contact details below: -

Figure A.11: LSS Survey Environmental Questions and Contact Details

Thank you for your input!



If you have any problems please contact James Marsh

Tel:0780 6505859 or Email: jamarsh8@my.shu.ac.uk

Figure A.12: LSS Survey Authors Contact Details

Appendix B: Minitab Analysis Method

B.1 Introduction

In the appendix the methods employed to conduct the statistical methods is outlined. These methods are an important part of the research as they outline the significant statistical similarities and differences between the key factors analysed.

The tests described are cross tabulation and Chi-Square in appendix B.2, Kruskal Wallis in appendix B.3 and Mann-Whitney in Appendix B.4.

B.2 Cross Tabulation and Chi-Square methodology

Filtered data from the Excel Spreadsheet is initially exported to Minitab for analysis. Selecting **Stat > Table > Descriptive Statistics** it is possible to select each individual defined variable (in this case geographic locations and Asia) and provide a total count each variable to be cross tabulated (in this case manufacturing and service sector types).

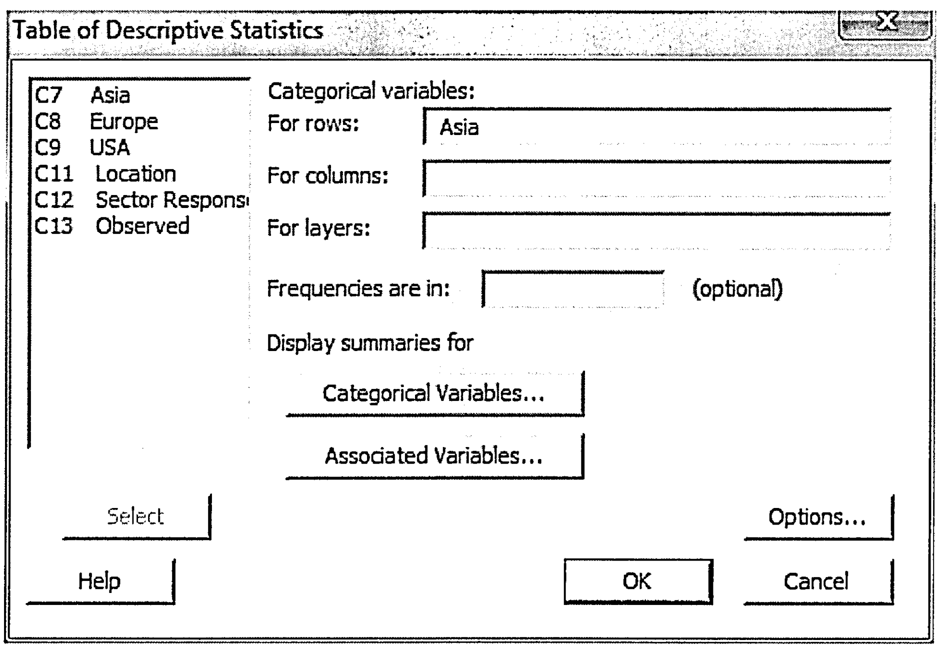


Figure B.1: Descriptive statistics method in Minitab

Once this has been conducted for all required variables (in this example Asia, Europe and USA) it is then necessary to manually input these counts into the Minitab worksheet, as shown in Figure B.2 below: -

C6	C7	C8	C9	C10	C11-T	C12	C13
	Asia	Europe	USA		Location	Sector Response	Observed
	1	1	1		Asia	0	39
	0	1	1		Asia	1	34
	0	0	0		Europe	0	66
	0	0	0		Europe	1	58
	0	0	0		USA	0	120
	1	0	0		USA	1	50
	1	0	0				
	0	0	1				
	0	0	1				

Figure B.2: Adding count data in Minitab worksheet

Once this has been completed it is then necessary to **select Stat > Table > Cross Tabulation and Chi Square** to conduct the analysis of the counts.

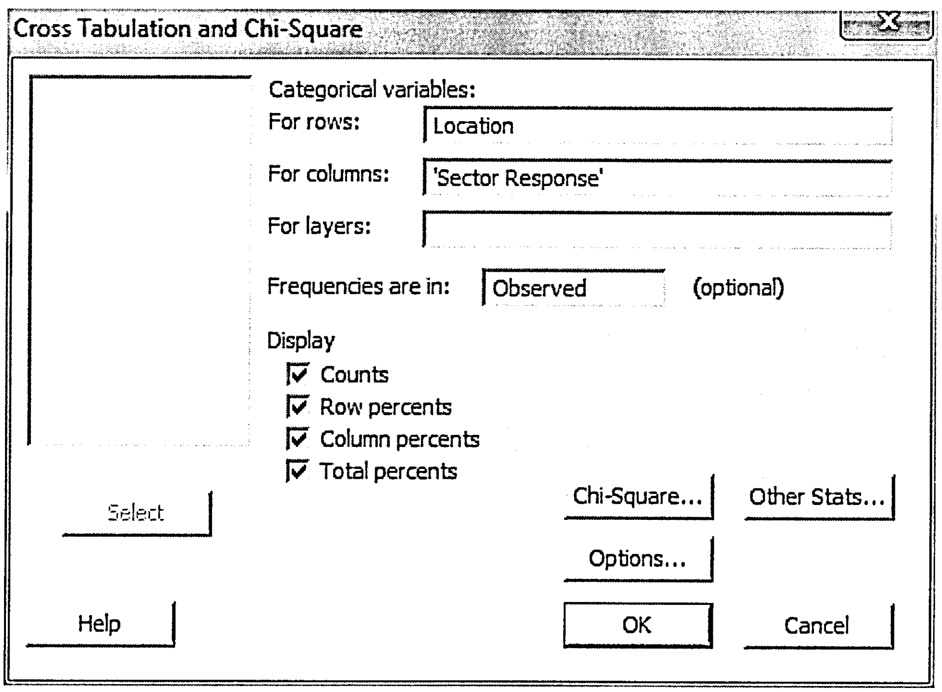
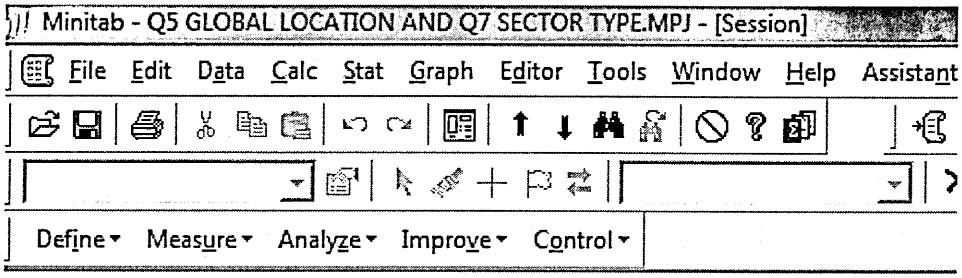


Figure B.3: Example Chi-Square method in Minitab

Subsequently the categorical variables should be selected as depicted in figure B.3. Also the tick boxes for the displayed outputs need to be selected and in addition the Chi-Square test. Once "OK" has been chosen the following tabulated statistics (figure B.4) will be displayed in the Minitab session window: -



Tabulated statistics: Location, Sector Response

```
Using frequencies in Observed


Rows: Location   Columns: Sector Response

                0        1      All

Asia        53.42    46.58   100.00
            17.33    23.94    19.89
            10.63     9.26    19.89

Europe      53.23    46.77   100.00
            29.33    40.85    33.79
            17.98    15.80    33.79

USA         70.59    29.41   100.00
            53.33    35.21    46.32
            32.70    13.62    46.32

All         61.31    38.69   100.00
           100.00   100.00   100.00
            61.31    38.69   100.00

Cell Contents:       % of Row
                     % of Column
                     % of Total


Pearson Chi-Square = 11.499, DF = 2, P-Value = 0.003
Likelihood Ratio Chi-Square = 11.624, DF = 2, P-Value = 0.003
```

Figure B.4: Example Tabulated Statistics for Chi-Square method in Minitab

The session window displays percentages for each variable (global location) cross tabulated with the other factor in this case industry sector represented by the 0 or 1. The session window also provides an output of the Chi-Square test in this example a P-Value of 0.003 is recorded. As this is less <0.05 then this it can be concluded that this test is statistically significant.

B.3 Kruskal-Wallis Tests

For questions where a rating scale exist Kruskal-Wallis non parametric analysis tools have been used within MINITAB. These series of tests allow for analysis of data containing medians rather than mean values. The test is performed in Minitab using **Stat > Nonparametrics > Kruskal-Wallis,** an example of this test for global location is shown in figure B.5 below: -

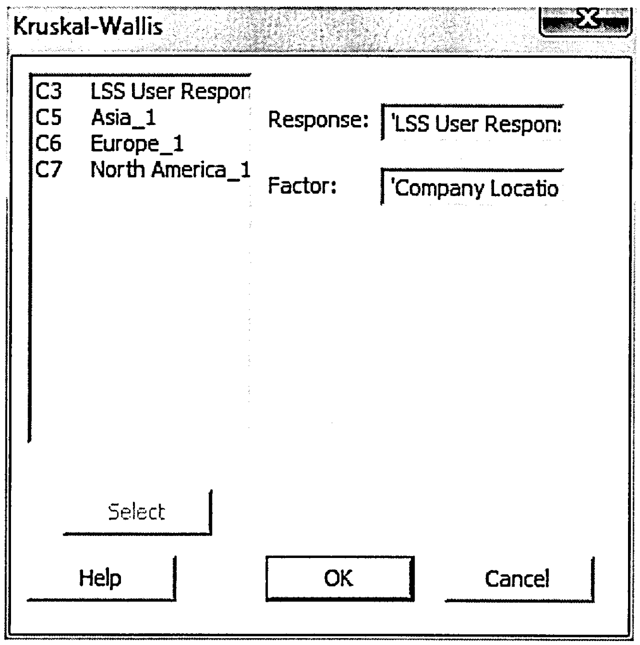


Figure B.5: Kruskal-Wallis Method in Minitab

After selecting the required response and factor, the Kruskal-Wallis Test will produce a series of test results in the session window. An example of this is depicted below in figure B.6

Kruskal-Wallis Test on LSS User Response

Company Location	N	Median	Ave Rank	Z
Asia	86	4.000	174.0	-2.44
Europe	136	4.000	209.3	1.03
North America	179	5.000	207.7	1.04
Overall	401		201.0	

H = 5.96 DF = 2 P = 0.051
H = 6.30 DF = 2 P = 0.043 (adjusted for ties)

Table B.6: Kruskal-Wallis Test – Global Location and LSS Experience

The results clarify the N for each variable that is being analysed along with the Median and Z values. It can be seen form this example that a P-Value of 0.043 has resulted from the analysis which indicates that there is a significant difference between the variables analysed (in this example the geographic locations and experience of LSS users).

B.4 Mann-Whitney Tests

For Kruskal Wallis tests where more than 2 variables are being tested and it is not clear where specifically the significant difference lies, secondary analysis is required and Mann Whitney tests are performed to clarify this.

This involves performing tests on two samples at a time. In this particular example 2 different geographic locations are tested. The figure depicts how this is conducted in Minitab using **Stat > Nonparametrics > Mann-Witney**.

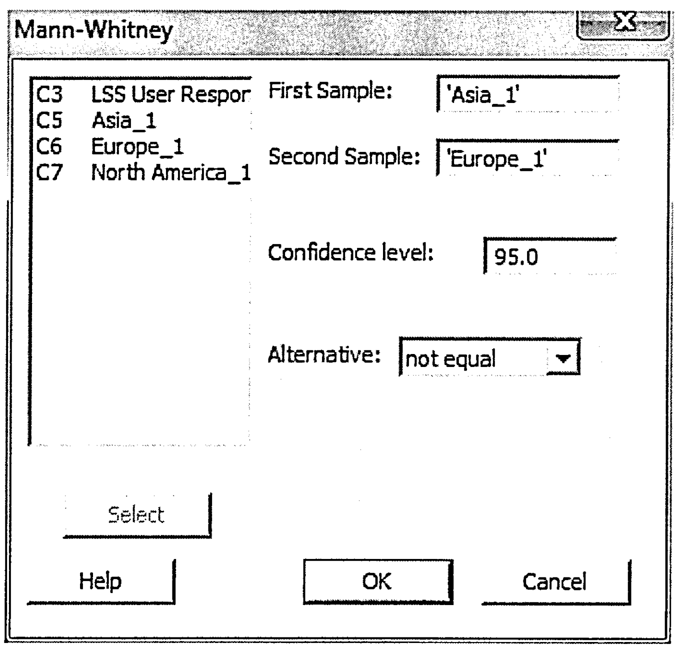


Figure B.7: Mann-Witney Method in Minitab

From the steps described above the Mann-Witney tests will produce a series of tabulated results in the session window, an example is depicted in figure B.8 which is examining 2 different global locations at a time in relation to the experience of LSS users.

```
Mann-Whitney Test and CI: Asia_1, Europe_1
             N  Median
Asia_1      86  4.0000
Europe_1   136  4.0000


Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (-1.0000,0.0001)
W = 8562.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0278
The test is significant at 0.0236 (adjusted for ties)

Mann-Whitney Test and CI: Asia_1, North America_1
                    N  Median
Asia_1             86  4.0000
North America_1   179  5.0000


Point estimate for ETA1-ETA2 is -1.0000
95.0 Percent CI for ETA1-ETA2 is (-1.0003,-0.0001)
W = 9498.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0009
The test is significant at 0.0006 (adjusted for ties)

Mann-Whitney Test and CI: Europe_1, North America_1
                    N  Median
Europe_1          136  4.0000
North America_1   179  5.0000


Point estimate for ETA1-ETA2 is -0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0001,-0.0001)
W = 20460.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.1994
The test is significant at 0.1863 (adjusted for ties)
```

Figure B.8: Example Mann-Witney test – Global location and LSS experience

From analysing these tests in figure B.8 it can be concluded that both North America and Europe are statistically different in terms of duration of experience than Asia. They both have longer experience of the LSS approach than Asia; however it can be concluded that statistically both the USA and Europe are the same in terms of duration experience.

Appendix C: Statistical Analysis Tests

Section 6 contains the detailed analysis of the extensive set of tests performed on the Global LSS survey and this appendix contains all the resulting tabulated statistics and statistical outputs from Minitab.

C.1 Geographic Location Tests

```
Using frequencies in Observed


Rows: Location   Columns: Sector Response

                0       1     All

Asia        53.42   46.58  100.00
            17.33   23.94   19.89
            10.63    9.26   19.89

Europe      53.23   46.77  100.00
            29.33   40.85   33.79
            17.98   15.80   33.79

USA         70.59   29.41  100.00
            53.33   35.21   46.32
            32.70   13.62   46.32

All         61.31   38.69  100.00
           100.00  100.00  100.00
            61.31   38.69  100.00

Pearson Chi-Square = 11.499, DF = 2, P-Value = 0.003
Likelihood Ratio Chi-Square = 11.624, DF = 2, P-Value = 0.003
```

Table C.1: Tabulated Statistics and Chi-Square Test for Global location and Business Sector

```
Kruskal-Wallis Test on LSS User Response

Company Location    N  Median  Ave Rank      Z
Asia               86   4.000     174.0  -2.44
Europe            136   4.000     209.3   1.03
North America     179   5.000     207.7   1.04
Overall           401             201.0

H = 5.96  DF = 2  P = 0.051
H = 6.30  DF = 2  P = 0.043  (adjusted for ties)
```

Table C.2: Kruskal-Wallis Test – Global Location and LSS Experience

```
Mann-Whitney Test and CI: Asia_1, Europe_1
             N  Median
Asia_1      86  4.0000
Europe_1   136  4.0000


Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (-1.0000,0.0001)
W = 8562.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0278
The test is significant at 0.0236 (adjusted for ties)

Mann-Whitney Test and CI: Asia_1, North America_1
                   N  Median
Asia_1            86  4.0000
North America_1  179  5.0000


Point estimate for ETA1-ETA2 is -1.0000
95.0 Percent CI for ETA1-ETA2 is (-1.0003,-0.0001)
W = 9498.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0009
The test is significant at 0.0006 (adjusted for ties)

Mann-Whitney Test and CI: Europe_1, North America_1
                   N  Median
Europe_1         136  4.0000
North America_1  179  5.0000


Point estimate for ETA1-ETA2 is -0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0001,-0.0001)
W = 20460.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.1994
The test is significant at 0.1863 (adjusted for ties)
```

Table C.3: Mann-Witney test – Global location and LSS experience

```
Kruskal-Wallis Test on LSS Benefits Response

Company Location    N  Median  Ave Rank      Z
Asia               84   4.000     213.2   1.43
Europe            134   4.000     196.0  -0.19
North America     176   4.000     191.1  -1.00
Overall           394             197.5

H = 2.18  DF = 2  P = 0.337
H = 2.77  DF = 2  P = 0.250  (adjusted for ties)
```

Table C.4: Kruskal-Wallis test - Global location and success of Lean and/or Six Sigma projects

```
Tabulated statistics: Location, Management Commitment Response
Pearson Chi-Square = 1.074, DF = 2, P-Value = 0.584
Likelihood Ratio Chi-Square = 1.071, DF = 2, P-Value = 0.585

Tabulated statistics: Location_1, Sustainability Response_1
Pearson Chi-Square = 0.426, DF = 2, P-Value = 0.808
Likelihood Ratio Chi-Square = 0.426, DF = 2, P-Value = 0.808

Tabulated statistics: Location_2, Stakeholder Involve Response_2
Pearson Chi-Square = 1.030, DF = 2, P-Value = 0.598
Likelihood Ratio Chi-Square = 1.029, DF = 2, P-Value = 0.598

Tabulated statistics: Location_3, History failed Projects_3
Pearson Chi-Square = 5.821, DF = 2, P-Value = 0.054
Likelihood Ratio Chi-Square = 5.957, DF = 2, P-Value = 0.051

Tabulated statistics: Location_4, Team LSS Knowledge_4
Pearson Chi-Square = 1.400, DF = 2, P-Value = 0.497
Likelihood Ratio Chi-Square = 1.432, DF = 2, P-Value = 0.489
```

Table C.5: Chi-Square test – Global location and biggest concerns over deployment of LSS

```
Tabulated statistics: Location_3_2, History failed Projects_3_2

Rows: Location_3_2   Columns: History failed Projects_3_2

             0       1     All

Asia     78.85   21.15  100.00
         38.32   20.37   32.30
         25.47    6.83   32.30
         1.096  -1.542       *

USA      60.55   39.45  100.00
         61.68   79.63   67.70
         40.99   26.71   67.70
        -0.757   1.065       *

All      66.46   33.54  100.00
        100.00  100.00  100.00
         66.46   33.54  100.00

Pearson Chi-Square = 5.287, DF = 1, P-Value = 0.021
Likelihood Ratio Chi-Square = 5.538, DF = 1, P-Value = 0.019
```

Table C.6: Chi-Square test – Global location and concern over history of failed projects

```
Kruskal-Wallis Test on LSS User Response

Company Location    N  Median  Ave Rank      Z
Asia               77   3.000     162.3   0.48
Europe            105   3.000     165.2   0.99
North America     133   3.000     149.8  -1.36
Overall           315             158.0

H = 1.90  DF = 2  P = 0.387
H = 2.04  DF = 2  P = 0.360  (adjusted for ties)
```

Table C.7: Kruskal Wallis test – Global location and Environmental benefits of LSS

```
Kruskal-Wallis Test on LSS User Response

Company Location     N  Median  Ave Rank      Z
Asia                71   1.000     164.6   2.69
Europe              98   1.000     135.4  -0.98
North America     114   1.000     133.6  -1.43
Overall            283             142.0

H = 7.28  DF = 2  P = 0.026
H = 10.00  DF = 2  P = 0.007  (adjusted for ties)
```

Table C.8: Kruskal-Wallis test – Global location and environmental negatives of LSS

```
Mann-Whitney Test and CI: Europe_1, North America_1
                    N  Median
Europe_1           98  1.0000
North America_1   114  1.0000

Point estimate for ETA1-ETA2 is -0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0000,-0.0001)
W = 10516.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.8592
The test is significant at 0.8292 (adjusted for ties)

Mann-Whitney Test and CI: Asia_1, North America_1
                    N  Median
Asia_1             71  1.0000
North America_1   114  1.0000

Mann-Whitney Test and CI: Asia_1, Europe_1

Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0001,-0.0002)
W = 7486.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0127
The test is significant at 0.0039 (adjusted for ties

                    N  Median
Asia_1             71  1.0000
Europe_1           98  1.0000

Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (0.0001,0.0000)
W = 6759.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0212
The test is significant at 0.0084 (adjusted for ties)
```

Table C.9: Mann-Witney test - Global location and environmental negatives of LSS

```
Tabulated statistics: Location, Green Lean Response
Pearson Chi-Square = 0.996, DF = 2, P-Value = 0.608
Likelihood Ratio Chi-Square = 1.015, DF = 2, P-Value = 0.602

Tabulated statistics: Location_1, Green Sigma Response_1
Pearson Chi-Square = 0.765, DF = 2, P-Value = 0.682
Likelihood Ratio Chi-Square = 0.793, DF = 2, P-Value = 0.673

Tabulated statistics: Location_2, Green Lean Six Sigma Response_2
Pearson Chi-Square = 1.729, DF = 2, P-Value = 0.421
Likelihood Ratio Chi-Square = 1.696, DF = 2, P-Value = 0.428

Tabulated statistics: Location_3, Non of the above_3
Pearson Chi-Square = 2.167, DF = 2, P-Value = 0.338
Likelihood Ratio Chi-Square = 2.133, DF = 2, P-Value = 0.344
```

Table C.10: Chi-Square tests – Global location and awareness of "Green" versions of Lean and/or Six Sigma

```
Tabulated statistics: Location, LSS EMS Response

Rows: Location   Columns: LSS EMS Response

              0       1       2     All

Asia       8.24   64.71   27.06  100.00
          13.21   25.35   17.69   21.25
           1.75   13.75    5.75   21.25

Europe    11.76   52.21   36.03  100.00
          30.19   32.72   37.69   34.00
           4.00   17.75   12.25   34.00

USA       16.76   50.84   32.40  100.00
          56.60   41.94   44.62   44.75
           7.50   22.75   14.50   44.75

All       13.25   54.25   32.50  100.00
         100.00  100.00  100.00  100.00
          13.25   54.25   32.50  100.00

Pearson Chi-Square = 7.002, DF = 4, P-Value = 0.136
Likelihood Ratio Chi-Square = 7.073, DF = 4, P-Value = 0.132
```

Table C.11: Chi-Square tests – Global location and value of combining LSS and Environmental Management.

Tabulated statistics: Location, LSS enhance EMS Response

Rows: Location   Columns: LSS enhance EMS Response

	0	1	2	All
Asia	5.88	72.94	21.18	100.00
	16.13	25.00	14.88	21.25
	1.25	15.50	4.50	21.25
Europe	6.62	56.62	36.76	100.00
	29.03	31.05	41.32	34.00
	2.25	19.25	12.50	34.00
USA	9.50	60.89	29.61	100.00
	54.84	43.95	43.80	44.75
	4.25	27.25	13.25	44.75
All	7.75	62.00	30.25	100.00
	100.00	100.00	100.00	100.00
	7.75	62.00	30.25	100.00

Pearson Chi-Square = 7.870, DF = 4, P-Value = 0.096
Likelihood Ratio Chi-Square = 7.950, DF = 4, P-Value = 0.093

Table C.12: Chi-Square test – Global location and LSS enhancing environmental practices

Tabulated statistics: Location, Impact of E-Legislation Response

Rows: Location   Columns: Impact of E-Legislation Response

	0	1	2	All
Asia	23.53	60.00	16.47	100.00
	16.67	24.76	18.92	21.25
	5.00	12.75	3.50	21.25
Europe	33.82	45.59	20.59	100.00
	38.33	30.10	37.84	34.00
	11.50	15.50	7.00	34.00
USA	30.17	51.96	17.88	100.00
	45.00	45.15	43.24	44.75
	13.50	23.25	8.00	44.75
All	30.00	51.50	18.50	100.00
	100.00	100.00	100.00	100.00
	30.00	51.50	18.50	100.00

Pearson Chi-Square = 4.521, DF = 4, P-Value = 0.340
Likelihood Ratio Chi-Square = 4.563, DF = 4, P-Value = 0.335

Table C.13: Chi-Square test – Global location and impact of environmental legislation

```
Kruskal-Wallis Test on LSS User Response

Company Location    N  Median  Ave Rank      Z
Asia               85   4.000     232.6   2.89
Europe            136   4.000     190.7  -1.21
North America     179   4.000     192.7  -1.22
Overall           400             200.5

H = 8.36  DF = 2  P = 0.015
H = 9.68  DF = 2  P = 0.008  (adjusted for ties)
```

Table C.14: Chi-Square test – Global location and personal environmental concern levels

```
Mann-Whitney Test and CI: Asia_1, Europe_1

             N  Median
Asia_1      85  4.0000
Europe_1   136  4.0000

Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (0.0000,0.9999)
W = 10633.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0096
The test is significant at 0.0051 (adjusted for ties)

Mann-Whitney Test and CI: Asia_1, North America_1

                    N  Median
Asia_1             85  4.0000
North America_1   179  4.0000

Point estimate for ETA1-ETA2 is -0.0000
95.0 Percent CI for ETA1-ETA2 is (0.0001,1.0000)
W = 12796.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0082
The test is significant at 0.0043 (adjusted for ties)

Mann-Whitney Test and CI: Europe_1, North America_1

                    N  Median
Europe_1          136  4.0000
North America_1   179  4.0000

Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0000,0.0000)
W = 21357.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.8705
The test is significant at 0.8615 (adjusted for ties)
```

Table C.15: Mann-Witney test - Global location and personal environmental concern levels

```
Tabulated statistics: Location 3, Energy Production Response
Pearson Chi-Square = 0.197, DF = 2, P-Value = 0.906
Likelihood Ratio Chi-Square = 0.197, DF = 2, P-Value = 0.906

Tabulated statistics: Location 4, People, animal health Response
Pearson Chi-Square = 3.012, DF = 2, P-Value = 0.222
Likelihood Ratio Chi-Square = 3.025, DF = 2, P-Value = 0.220
```

Table C.16: Chi-Square test – Global location and types of environmental concern

```
Tabulated statistics: Location, General Waste land/sea Response

Rows: Location   Columns: General Waste land/sea Response

               0       1     All

Asia       48.24   51.76  100.00
           29.08   17.12   21.36
           10.30   11.06   21.36

Europe     32.84   67.16  100.00
           31.21   35.02   33.67
           11.06   22.61   33.67

USA        31.28   68.72  100.00
           39.72   47.86   44.97
           14.07   30.90   44.97

All        35.43   64.57  100.00
          100.00  100.00  100.00
           35.43   64.57  100.00

Pearson Chi-Square = 7.831, DF = 2, P-Value = 0.020
Likelihood Ratio Chi-Square = 7.617, DF = 2, P-Value = 0.022
```

Table C.17: Chi-Square test – Global location and general waste land/sea response

```
Tabulated statistics: Location 1, Air Quality Response

Rows: Location 1   Columns: Air Quality Response

               0       1     All

Asia       30.59   69.41  100.00
           17.45   23.51   21.25
            6.50   14.75   21.25

Europe     46.32   53.68  100.00
           42.28   29.08   34.00
           15.75   18.25   34.00

USA        33.52   66.48  100.00
           40.27   47.41   44.75
           15.00   29.75   44.75

All        37.25   62.75  100.00
          100.00  100.00  100.00
           37.25   62.75  100.00

Pearson Chi-Square = 7.470, DF = 2, P-Value = 0.024
Likelihood Ratio Chi-Square = 7.407, DF = 2, P-Value = 0.025
```

Table C.18: Chi-Square test – Global location and air quality response

```
Tabulated statistics: Location 2, Water Quality Response

Rows: Location 2   Columns: Water Quality Response

               0        1      All

Asia       31.76    68.24   100.00
           17.65    23.48    21.25
            6.75    14.50    21.25

Europe     54.41    45.59   100.00
           48.37    25.10    34.00
           18.50    15.50    34.00

USA        29.05    70.95   100.00
           33.99    51.42    44.75
           13.00    31.75    44.75

All        38.25    61.75   100.00
          100.00   100.00   100.00
           38.25    61.75   100.00

Pearson Chi-Square = 22.968, DF = 2, P-Value = 0.000
Likelihood Ratio Chi-Square = 22.749, DF = 2, P-Value = 0.000
```

Table C.19: Chi-Square test – Global location and water quality response

```
Tabulated statistics: Location, Legislation Response

Rows: Location   Columns: Legislation Response

               0        1      All

Asia       45.88    54.12   100.00
           24.38    19.17    21.25
            9.75    11.50    21.25

Europe     29.41    70.59   100.00
           25.00    40.00    34.00
           10.00    24.00    34.00

USA        45.25    54.75   100.00
           50.63    40.83    44.75
           20.25    24.50    44.75

All        40.00    60.00   100.00
          100.00   100.00   100.00
           40.00    60.00   100.00

Pearson Chi-Square = 9.635, DF = 2, P-Value = 0.008
Likelihood Ratio Chi-Square = 9.845, DF = 2, P-Value = 0.007
```

Table C.20: Chi-Square test – Global location and key drivers towards going "green"

Tabulated statistics: Location, LSS and EMS Teams Response

Using frequencies in Observed

Rows: Location   Columns: LSS and EMS Teams Response

	0	1	All
Asia	34.38	65.63	100.00
	16.30	27.27	22.15
	7.61	14.53	22.15
Europe	59.79	40.21	100.00
	42.96	25.32	33.56
	20.07	13.49	33.56
USA	42.97	57.03	100.00
	40.74	47.40	44.29
	19.03	25.26	44.29
All	46.71	53.29	100.00
	100.00	100.00	100.00
	46.71	53.29	100.00

Pearson Chi-Square = 11.303, DF = 2, P-Value = 0.004
Likelihood Ratio Chi-Square = 11.391, DF = 2, P-Value = 0.003

Table C.21: Chi-Square test - Global location and LSS & environmental employees working together on improvement projects

Using frequencies in Observed

Rows: Location   Columns: Green 7 Waste Response

	0	1	All
Asia	15.12	84.88	100.00
	17.11	22.46	21.45
	3.24	18.20	21.45
Europe	15.44	84.56	100.00
	27.63	35.38	33.92
	5.24	28.68	33.92
USA	23.46	76.54	100.00
	55.26	42.15	44.64
	10.47	34.16	44.64
All	18.95	81.05	100.00
	100.00	100.00	100.00
	18.95	81.05	100.00

Pearson Chi-Square = 4.287, DF = 2, P-Value = 0.117
Likelihood Ratio Chi-Square = 4.264, DF = 2, P-Value = 0.119

Table C.22: Chi-Square test – Global location and green 7 waste response

```
Using frequencies in Observed 1

Rows: Location 1   Columns: Green 5S Response

               0        1     All

Asia       30.23    69.77  100.00
           21.14    21.58   21.45
            6.48    14.96   21.45

Europe     33.82    66.18  100.00
           37.40    32.37   33.92
           11.47    22.44   33.92

USA        28.49    71.51  100.00
           41.46    46.04   44.64
           12.72    31.92   44.64

All        30.67    69.33  100.00
          100.00   100.00  100.00
           30.67    69.33  100.00

Cell Contents:        % of Row
                      % of Column
                      % of Total


Pearson Chi-Square = 1.043, DF = 2, P-Value = 0.594
Likelihood Ratio Chi-Square = 1.037, DF = 2, P-Value = 0.595
```

Table C.23: Chi-Square test – Global location and green 5S response

```
Using frequencies in Observed 2

Rows: Location 2   Columns: Green VSM Response

               0        1     All

Asia       54.12    45.88  100.00
           27.38    16.81   21.25
           11.50     9.75   21.25

Europe     38.24    61.76  100.00
           30.95    36.21   34.00
           13.00    21.00   34.00

USA        39.11    60.89  100.00
           41.67    46.98   44.75
           17.50    27.25   44.75

All        42.00    58.00  100.00
          100.00   100.00  100.00
           42.00    58.00  100.00

Pearson Chi-Square = 6.530, DF = 2, P-Value = 0.038
Likelihood Ratio Chi-Square = 6.459, DF = 2, P-Value = 0.040
```

Table C.24: Chi-Square test – Global location and green VSM response

```
Using frequencies in Observed 3


Rows: Location 3   Columns: Green Kaizen Response

                0       1     All

Asia        44.19   55.81  100.00
            22.49   20.69   21.45
             9.48   11.97   21.45

Europe      47.79   52.21  100.00
            38.46   30.60   33.92
            16.21   17.71   33.92

USA         36.87   63.13  100.00
            39.05   48.71   44.64
            16.46   28.18   44.64

All         42.14   57.86  100.00
           100.00  100.00  100.00
            42.14   57.86  100.00

Pearson Chi-Square = 3.968, DF = 2, P-Value = 0.137
Likelihood Ratio Chi-Square = 3.978, DF = 2, P-Value = 0.137
```

Table C.25: Chi-Square test – Global location and green 7 Kaizen responses

```
Using frequencies in Observed 4


Rows: Location 4   Columns: Green Process Mapping

                0       1     All

Asia        48.84   51.16  100.00
            25.15   19.13   21.66
            10.58   11.08   21.66

Europe      38.64   61.36  100.00
            30.54   35.22   33.25
            12.85   20.40   33.25

USA         41.34   58.66  100.00
            44.31   45.65   45.09
            18.64   26.45   45.09

All         42.07   57.93  100.00
           100.00  100.00  100.00
            42.07   57.93  100.00

Pearson Chi-Square = 2.294, DF = 2, P-Value = 0.318
Likelihood Ratio Chi-Square = 2.281, DF = 2, P-Value = 0.320
```

Table C.26: Chi-Square test – Global location and green process mapping

C.2 Business Sector Tests

```
Kruskal-Wallis Test on LSS Scale Response

Business Sector     N  Median  Ave Rank      Z
Manufacturing     233   4.000     197.2   0.48
Service           156   4.000     191.7  -0.48
Overall           389             195.0

H = 0.23  DF = 1  P = 0.632
H = 0.24  DF = 1  P = 0.623  (adjusted for ties)
```

Table C.27: Kruskal-Wallis Test – Business sector and LSS experience

```
Kruskal-Wallis Test on LSS Benefits Response

Business Sector     N  Median  Ave Rank      Z
Manufacturing     229   4.000     188.8  -0.69
Service           154   4.000     196.8   0.69
Overall           383             192.0

H = 0.48  DF = 1  P = 0.489
H = 0.61  DF = 1  P = 0.435  (adjusted for ties)
```

Table C.28: Kruskal-Wallis test – Business sector and success of Lean and/or Six Sigma projects

```
Management Commitment Response

Pearson Chi-Square = 0.329, DF = 1, P-Value = 0.566
Likelihood Ratio Chi-Square = 0.328, DF = 1, P-Value = 0.567

Sustainability Response_1

Pearson Chi-Square = 0.406, DF = 1, P-Value = 0.524
Likelihood Ratio Chi-Square = 0.406, DF = 1, P-Value = 0.524

Stakeholder Involve Response_2

Pearson Chi-Square = 0.896, DF = 1, P-Value = 0.344
Likelihood Ratio Chi-Square = 0.895, DF = 1, P-Value = 0.344

History failed Projects_3
Pearson Chi-Square = 3.743, DF = 1, P-Value = 0.053
Likelihood Ratio Chi-Square = 3.785, DF = 1, P-Value = 0.052

Team LSS Knowledge_4

Pearson Chi-Square = 0.212, DF = 1, P-Value = 0.645
Likelihood Ratio Chi-Square = 0.213, DF = 1, P-Value = 0.645
```

Table C.29: Chi-Square test – Business sector and biggest concerns over deployment of LSS

```
History failed Projects_3

                    0       1      All

Manufacturing    63.64   36.36  100.00
                 50.60   64.00   54.77
                 34.85   19.92   54.77

Service          75.23   24.77  100.00
                 49.40   36.00   45.23
                 34.02   11.20   45.23

All              68.88   31.12  100.00
                100.00  100.00  100.00
                 68.88   31.12  100.00

Pearson Chi-Square = 3.743, DF = 1, P-Value = 0.053
Likelihood Ratio Chi-Square = 3.785, DF = 1, P-Value = 0.052
```

Table C.30: Chi-Square test – Business sector and history of failed projects response

```
Kruskal-Wallis Test on LSS User Response

Business Sector     N  Median  Ave Rank      Z
Manufacturing     186   3.000     151.8  -0.42
Service           120   3.000     156.2   0.42
Overall           306             153.5

H = 0.18  DF = 1  P = 0.674
H = 0.19  DF = 1  P = 0.662  (adjusted for ties)
```

Table C.31: Kruskal Wallis test – Business sector and Environmental benefits of LSS

```
Kruskal-Wallis Test on LSS User Response

Business Sector     N  Median  Ave Rank      Z
Manufacturing     165   1.000     140.5   0.52
Service           111   1.000     135.5  -0.52
Overall           276             138.5

H = 0.27  DF = 1  P = 0.605
H = 0.37  DF = 1  P = 0.543  (adjusted for ties)
```

Table C.32: Kruskal-Wallis test – Business sector and environmental negatives of LSS

```
Tabulated statistics: Sector, Green Lean Response
Pearson Chi-Square = 1.684, DF = 1, P-Value = 0.194
Likelihood Ratio Chi-Square = 1.666, DF = 1, P-Value = 0.197
```

Table C.33: Chi-Square tests – Business sector and awareness of "Green" Lean response

```
Tabulated statistics: Sector_1, Green Sigma Response_1

Rows: Sector_1   Columns: Green Sigma Response_1

                    0       1     All

Manufacturing   96.14    3.86  100.00
                61.20   39.13   59.90
                57.58    2.31   59.90

Service         91.03    8.97  100.00
                38.80   60.87   40.10
                36.50    3.60   40.10

All             94.09    5.91  100.00
               100.00  100.00  100.00
                94.09    5.91  100.00

Pearson Chi-Square = 4.389, DF = 1, P-Value = 0.036
Likelihood Ratio Chi-Square = 4.281, DF = 1, P-Value = 0.039
```

Table C.34: Chi-Square tests – Business sector and awareness of "Green" Sigma response

```
Tabulated statistics: Sector_2, Green Lean Six Sigma Response_2

Rows: Sector_2   Columns: Green Lean Six Sigma Response_2

                    0       1     All

Manufacturing   90.99    9.01  100.00
                62.17   43.75   59.90
                54.50    5.40   59.90

Service         82.69   17.31  100.00
                37.83   56.25   40.10
                33.16    6.94   40.10

All             87.66   12.34  100.00
               100.00  100.00  100.00
                87.66   12.34  100.00

Pearson Chi-Square = 5.944, DF = 1, P-Value = 0.015
Likelihood Ratio Chi-Square = 5.816, DF = 1, P-Value = 0.016
```

Table C.35: Chi-Square tests – Business sector and awareness of "Green" Lean Six Sigma response

```
Tabulated statistics: Sector_3, Non of the above_3

Rows: Sector_3   Columns: Non of the above_3

                     0        1      All

Manufacturing    27.90    72.10   100.00
                 52.00    63.64    59.90
                 16.71    43.19    59.90

Service          38.46    61.54   100.00
                 48.00    36.36    40.10
                 15.42    24.68    40.10

All              32.13    67.87   100.00
                100.00   100.00   100.00
                 32.13    67.87   100.00

Pearson Chi-Square = 4.782, DF = 1, P-Value = 0.029
Likelihood Ratio Chi-Square = 4.745, DF = 1, P-Value = 0.029
```

Table C.36: Chi-Square tests – Business sector and awareness of "none of the above" response

```
Tabulated statistics: Sector, LSS EMS Response

Rows: Sector   Columns: LSS EMS Response

                     0        1        2      All

Manufacturing    14.16    50.64    35.19   100.00
                 66.00    55.66    64.57    59.90
                  8.48    30.33    21.08    59.90

Service          10.90    60.26    28.85   100.00
                 34.00    44.34    35.43    40.10
                  4.37    24.16    11.57    40.10

All              12.85    54.50    32.65   100.00
                100.00   100.00   100.00   100.00
                 12.85    54.50    32.65   100.00

Pearson Chi-Square = 3.512, DF = 2, P-Value = 0.173
Likelihood Ratio Chi-Square = 3.529, DF = 2, P-Value = 0.171
```

Table C.37: Chi-Square tests – Business sector and value of combining LSS and environmental management

Tabulated statistics: Sector, LSS enhance EMS Response

Rows: Sector Columns: LSS enhance EMS Response

	0	1	2	All
Manufacturing	9.87	60.09	30.04	100.00
	76.67	57.14	61.40	59.90
	5.91	35.99	17.99	59.90
Service	4.49	67.31	28.21	100.00
	23.33	42.86	38.60	40.10
	1.80	26.99	11.31	40.10
All	7.71	62.98	29.31	100.00
	100.00	100.00	100.00	100.00
	7.71	62.98	29.31	100.00

Pearson Chi-Square = 4.394, DF = 2, P-Value = 0.111
Likelihood Ratio Chi-Square = 4.649, DF = 2, P-Value = 0.098

Table C.38: Chi-Square test – Business sector and LSS enhancing environmental practices

Tabulated statistics: Sector, Impact of E-Legislation Response

Rows: Sector Columns: Impact of E-Legislation Response

	0	1	2	All
Manufacturing	24.89	57.51	17.60	100.00
	50.43	65.37	59.42	59.90
	14.91	34.45	10.54	59.90
Service	36.54	45.51	17.95	100.00
	49.57	34.63	40.58	40.10
	14.65	18.25	7.20	40.10
All	29.56	52.70	17.74	100.00
	100.00	100.00	100.00	100.00
	29.56	52.70	17.74	100.00

Pearson Chi-Square = 6.846, DF = 2, P-Value = 0.033
Likelihood Ratio Chi-Square = 6.808, DF = 2, P-Value = 0.033

Table C.39: Chi-Square test – Business sector and impact of environmental legislation

```
Kruskal-Wallis Test on LSS User Response

Company Sector    N  Median  Ave Rank      Z
Manufacturing   233   4.000     195.0   0.00
Service         156   4.000     195.0  -0.00
Overall         389             195.0

H = 0.00  DF = 1  P = 0.996
H = 0.00  DF = 1  P = 0.996  (adjusted for ties)
```

Table C.40: Kruskal-Wallis test – Business sector and personal environmental concern levels

```
Tabulated statistics: Sector, General Waste land/sea Response
Pearson Chi-Square = 0.098, DF = 1, P-Value = 0.754
Likelihood Ratio Chi-Square = 0.098, DF = 1, P-Value = 0.754

Tabulated statistics: Sector 1, Air Quality Response
Pearson Chi-Square = 0.423, DF = 1, P-Value = 0.515
Likelihood Ratio Chi-Square = 0.422, DF = 1, P-Value = 0.516

Tabulated statistics: Sector 2, Water Quality Response
Pearson Chi-Square = 0.026, DF = 1, P-Value = 0.873
Likelihood Ratio Chi-Square = 0.026, DF = 1, P-Value = 0.873

Tabulated statistics: Sector 3, Energy Production Response
Pearson Chi-Square = 0.351, DF = 1, P-Value = 0.554
Likelihood Ratio Chi-Square = 0.351, DF = 1, P-Value = 0.554

Tabulated statistics: Sector 4, People, animal health Response
Pearson Chi-Square = 0.496, DF = 1, P-Value = 0.481
Likelihood Ratio Chi-Square = 0.496, DF = 1, P-Value = 0.481
```

Table C.41: Chi-Square test – Business sector and types of environmental concern

```
Tabulated statistics: Sector, Legislation Response

Rows: Sector   Columns: Legislation Response

                     0       1     All

Manufacturing    32.19   67.81  100.00
                 49.34   66.67   59.90
                 19.28   40.62   59.90

Service          49.36   50.64  100.00
                 50.66   33.33   40.10
                 19.79   20.31   40.10

All              39.07   60.93  100.00
                100.00  100.00  100.00
                 39.07   60.93  100.00

Pearson Chi-Square = 11.571, DF = 1, P-Value = 0.001
Likelihood Ratio Chi-Square = 11.528, DF = 1, P-Value = 0.001
```

Table C.42: Chi-Square test – Business sector and key drivers towards going "green"

Tabulated statistics: Sector, LSS and EMS Teams Response

Rows: Sector   Columns: LSS and EMS Teams Response

	0	1	2	All
Manufacturing	33.48	40.34	26.18	100.00
	57.35	63.95	57.55	59.90
	20.05	24.16	15.68	59.90
Service	37.18	33.97	28.85	100.00
	42.65	36.05	42.45	40.10
	14.91	13.62	11.57	40.10
All	34.96	37.79	27.25	100.00
	100.00	100.00	100.00	100.00
	34.96	37.79	27.25	100.00

Pearson Chi-Square = 1.613, DF = 2, P-Value = 0.446
Likelihood Ratio Chi-Square = 1.622, DF = 2, P-Value = 0.444

Table C.43: Chi-Square test – Business sector and LSS & environmental employees working together on improvement projects

Tabulated statistics: Sector 1, Green 5S Response

Rows: Sector 1   Columns: Green 5S Response

	0	1	All
Manufacturing	24.46	75.54	100.00
	47.90	65.19	59.90
	14.65	45.24	59.90
Service	39.74	60.26	100.00
	52.10	34.81	40.10
	15.94	24.16	40.10
All	30.59	69.41	100.00
	100.00	100.00	100.00
	30.59	69.41	100.00

Pearson Chi-Square = 10.275, DF = 1, P-Value = 0.001
Likelihood Ratio Chi-Square = 10.169, DF = 1, P-Value = 0.001

Table C.44: Chi-Square test – Business sector and green 5S

C.3 Company Structure Tests

```
Kruskal-Wallis Test on LSS User Response

Structure                  N  Median  Ave Rank      Z
Limited                  133   4.000     183.6  -1.73
Public Limited Company   201   4.000     201.3   0.67
ST and PTS                60   5.000     215.7   1.34
Overall                  394             197.5

H = 3.73  DF = 2  P = 0.155
H = 3.95  DF = 2  P = 0.139  (adjusted for ties)
```

Table C.45: Kruskal-Wallis Test – Company structure and LSS experience

```
Source   DF      SS    MS     F      P
Factor    2    9.01  4.51  2.37  0.095
Error   391  742.63  1.90
Total   393  751.64

S = 1.378   R-Sq = 1.20%   R-Sq(adj) = 0.69%


                               Individual 95% CIs For Mean Based on
                               Pooled StDev
Level         N   Mean  StDev  ---------+---------+---------+---------+
ST and PTS   60  4.600  1.330            (----------*-----------)
LTD         133  4.173  1.443  (-------*-------)
PLC         201  4.428  1.348           (------*-----)
                               ---------+---------+---------+---------+
                                      4.20      4.50      4.80      5.10

Pooled StDev = 1.378
```

Table C.46: ANOVA analysis - Company structure and LSS experience

```
Kruskal-Wallis Test on LSS Benefits Response

Structure                  N  Median  Ave Rank      Z
Limited                  133   4.000     209.0   1.83
Public Limited Company   198   4.000     187.8  -1.21
ST and PTS                57   4.000     184.1  -0.76
Overall                  388             194.5

H = 3.41  DF = 2  P = 0.182
H = 4.33  DF = 2  P = 0.115  (adjusted for ties)
```

Table C.47: Kruskal-Wallis test – Company structure and success of Lean and/or Six Sigma projects

```
Tabulated statistics: Structure, Management Commitment Response
Pearson Chi-Square = 0.419, DF = 2, P-Value = 0.811
Likelihood Ratio Chi-Square = 0.416, DF = 2, P-Value = 0.812

Tabulated statistics: Structure_1, Sustainability Response_1
Pearson Chi-Square = 5.462, DF = 2, P-Value = 0.065
Likelihood Ratio Chi-Square = 5.472, DF = 2, P-Value = 0.065

Tabulated statistics: Structure_2, Stakeholder Involve Response_2
Pearson Chi-Square = 2.691, DF = 2, P-Value = 0.260
Likelihood Ratio Chi-Square = 2.817, DF = 2, P-Value = 0.245

Tabulated statistics: Structure_3, History failed Projects_3
Pearson Chi-Square = 0.088, DF = 2, P-Value = 0.957
Likelihood Ratio Chi-Square = 0.088, DF = 2, P-Value = 0.957

Tabulated statistics: Structure_4, Team LSS Knowledge_4
Pearson Chi-Square = 1.040, DF = 2, P-Value = 0.594
Likelihood Ratio Chi-Square = 1.052, DF = 2, P-Value = 0.591
```

Table C.48: Chi-Square test – Company structure and biggest concerns over deployment of LSS

```
Kruskal-Wallis Test on LSS User Response

Structure                  N  Median  Ave Rank      Z
Limited                  110   3.000     171.9   2.14
Public Limited Company   151   3.000     149.1  -1.48
ST and PTS                52   3.000     148.3  -0.76
Overall                  313             157.0

H = 4.59  DF = 2  P = 0.101
H = 4.93  DF = 2  P = 0.085  (adjusted for ties)
```

Table C.49: Kruskal Wallis test – Company structure and Environmental benefits of LSS

```
      N  Median
LTD  110  3.0000
PLC  151  3.0000

Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0001,1.0000)
W = 15645.5
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.0201
The test is significant at 0.0166 (adjusted for ties)
```

Table C.50: Mann-Witney tests - Company structure and Environmental benefits of LSS

```
Kruskal-Wallis Test on LSS User Response

Structure                  N  Median  Ave Rank      Z
Limited                  103   1.000     140.4  -0.25
Public Limited Company   132   1.000     136.6  -1.03
ST and PTS                48   1.000     160.2   1.69
Overall                  283             142.0

H = 2.99  DF = 2  P = 0.224
H = 4.01  DF = 2  P = 0.135  (adjusted for ties)
```

Table C.51: Kruskal-Wallis test – Company structure and environmental negatives of LSS

```
Tabulated statistics: Structure, Green Lean Response
Pearson Chi-Square = 3.287, DF = 2, P-Value = 0.193
Likelihood Ratio Chi-Square = 3.197, DF = 2, P-Value = 0.202

Tabulated statistics: Structure_1, Green Sigma Response_1
Pearson Chi-Square = 3.644, DF = 2, P-Value = 0.162
Likelihood Ratio Chi-Square = 3.556, DF = 2, P-Value = 0.169

Tabulated statistics: Structure_2, Green Lean Six Sigma Response_2
Pearson Chi-Square = 2.052, DF = 2, P-Value = 0.359
Likelihood Ratio Chi-Square = 2.045, DF = 2, P-Value = 0.360
```

Table C.52: Chi-Square tests – Company structure and awareness of green Lean and/or Six Sigma response

```
Using frequencies in Observed_3


Rows: Structure_3   Columns: Non of the above_3

                 0        1      All

LTD          36.84    63.16   100.00
             38.89    31.34    33.76
             12.44    21.32    33.76

PLC          25.37    74.63   100.00
             40.48    55.97    51.02
             12.94    38.07    51.02

ST/PTS       43.33    56.67   100.00
             20.63    12.69    15.23
              6.60     8.63    15.23

All          31.98    68.02   100.00
            100.00   100.00   100.00
             31.98    68.02   100.00

Pearson Chi-Square = 9.034, DF = 2, P-Value = 0.011
Likelihood Ratio Chi-Square = 8.996, DF = 2, P-Value = 0.011
```

Table C.53: Chi-Square tests – Company structure and awareness of none of the above

Using frequencies in Observed

Rows: Structure   Columns: LSS EMS Response

	0	1	2	All
LTD	10.53	61.65	27.82	100.00
	26.42	39.05	28.24	33.76
	3.55	20.81	9.39	33.76
PLC	13.43	49.25	37.31	100.00
	50.94	47.14	57.25	51.02
	6.85	25.13	19.04	51.02
ST/PTS	20.00	48.33	31.67	100.00
	22.64	13.81	14.50	15.23
	3.05	7.36	4.82	15.23
All	13.45	53.30	33.25	100.00
	100.00	100.00	100.00	100.00
	13.45	53.30	33.25	100.00

Pearson Chi-Square = 7.619, DF = 4, P-Value = 0.107
Likelihood Ratio Chi-Square = 7.409, DF = 4, P-Value = 0.116

Table C.54: Chi-Square tests – Company structure and value of combining LSS and environmental management

Using frequencies in Observed

Rows: Structure   Columns: LSS enhance EMS Response

	0	1	2	All
LTD	6.77	64.66	28.57	100.00
	28.13	35.68	31.40	33.76
	2.28	21.83	9.64	33.76
PLC	8.46	58.71	32.84	100.00
	53.13	48.96	54.55	51.02
	4.31	29.95	16.75	51.02
ST/PTS	10.00	61.67	28.33	100.00
	18.75	15.35	14.05	15.23
	1.52	9.39	4.31	15.23
All	8.12	61.17	30.71	100.00
	100.00	100.00	100.00	100.00
	8.12	61.17	30.71	100.00

Cell Contents: % of Row
% of Column
% of Total

Pearson Chi-Square = 1.660, DF = 4, P-Value = 0.798
Likelihood Ratio Chi-Square = 1.659, DF = 4, P-Value = 0.798

Table C.55: Chi-Square test – Company structure and LSS enhancing environmental practices

Using frequencies in Observed

Rows: Structure   Columns: Impact of E-Legislation Response

	0	1	2	All
LTD	28.57	54.89	16.54	100.00
	33.04	35.10	30.99	33.76
	9.64	18.53	5.58	33.76
PLC	27.86	51.74	20.40	100.00
	48.70	50.00	57.75	51.02
	14.21	26.40	10.41	51.02
ST/PTS	35.00	51.67	13.33	100.00
	18.26	14.90	11.27	15.23
	5.33	7.87	2.03	15.23
All	29.19	52.79	18.02	100.00
	100.00	100.00	100.00	100.00
	29.19	52.79	18.02	100.00

Pearson Chi-Square = 2.524, DF = 4, P-Value = 0.640
Likelihood Ratio Chi-Square = 2.534, DF = 4, P-Value = 0.639

Table C.56: Chi-Square test – Company Structure and impact of environmental legislation

Kruskal-Wallis Test on LSS User Response

Structure	N	Median	Ave Rank	Z
Limited	133	4.000	198.7	0.16
Public Limited Company	201	4.000	193.9	-0.65
ST and PTS	60	4.000	206.9	0.70
Overall	394		197.5	

H = 0.63 DF = 2 P = 0.729
H = 0.73 DF = 2 P = 0.693 (adjusted for ties)

Table C.57: Kruskal-Wallis test – Company structure and personal environmental concern levels

```
Tabulated statistics: Structure, General Waste land/sea Response
Pearson Chi-Square = 0.386, DF = 2, P-Value = 0.824
Likelihood Ratio Chi-Square = 0.384, DF = 2, P-Value = 0.825

Tabulated statistics: Structure 1, Air Quality Response
Pearson Chi-Square = 7.108, DF = 2, P-Value = 0.029
Likelihood Ratio Chi-Square = 6.988, DF = 2, P-Value = 0.030

Tabulated statistics: Structure 2, Water Quality Response
Pearson Chi-Square = 2.993, DF = 2, P-Value = 0.224
Likelihood Ratio Chi-Square = 3.018, DF = 2, P-Value = 0.221

Tabulated statistics: Structure 3, Energy Production Response
Pearson Chi-Square = 3.596, DF = 2, P-Value = 0.166
Likelihood Ratio Chi-Square = 3.624, DF = 2, P-Value = 0.163

Tabulated statistics: Structure 4, People, animal health Response
Pearson Chi-Square = 1.078, DF = 2, P-Value = 0.583
Likelihood Ratio Chi-Square = 1.082, DF = 2, P-Value = 0.582
```

Table C.58: Chi-Square test – Company Structure and types of environmental concern

Using frequencies in Observed 1

Rows: Structure 1 Columns: Air Quality Response

	0	1	All
LTD	39.10	60.90	100.00
	34.90	33.06	33.76
	13.20	20.56	33.76
PLC	32.84	67.16	100.00
	44.30	55.10	51.02
	16.75	34.26	51.02
ST/PTS	51.67	48.33	100.00
	20.81	11.84	15.23
	7.87	7.36	15.23
All	37.82	62.18	100.00
	100.00	100.00	100.00
	37.82	62.18	100.00

Table C.59: Tabulated statistics – Company structure and air quality response

```
Tabulated statistics: Structure, Legislation Response
Pearson Chi-Square = 3.130, DF = 2, P-Value = 0.209
Likelihood Ratio Chi-Square = 3.099, DF = 2, P-Value = 0.212

Tabulated statistics: Structure 1, Customers Response
Pearson Chi-Square = 0.980, DF = 2, P-Value = 0.613
Likelihood Ratio Chi-Square = 0.976, DF = 2, P-Value = 0.614

Tabulated statistics: Structure 2, Economic Demands Response
Pearson Chi-Square = 2.508, DF = 2, P-Value = 0.285
Likelihood Ratio Chi-Square = 2.511, DF = 2, P-Value = 0.285

Tabulated statistics: Structure 3, New Opportunities Response
Pearson Chi-Square = 1.078, DF = 2, P-Value = 0.583
Likelihood Ratio Chi-Square = 1.086, DF = 2, P-Value = 0.581

Tabulated statistics: Structure 4, Competitors Response
Pearson Chi-Square = 2.700, DF = 2, P-Value = 0.259
Likelihood Ratio Chi-Square = 2.666, DF = 2, P-Value = 0.264
```

Table C.60: Chi-Square test – Company structure and key drivers towards going "green"

```
Using frequencies in Observed


Rows: Structure   Columns: LSS and EMS Teams Response

                0       1       2     All

LTD         35.34   41.35   23.31  100.00
            35.07   35.95   28.97   33.76
            11.93   13.96    7.87   33.76

PLC         34.33   35.82   29.85  100.00
            51.49   47.06   56.07   51.02
            17.51   18.27   15.23   51.02

ST/PTS      30.00   43.33   26.67  100.00
            13.43   16.99   14.95   15.23
             4.57    6.60    4.06   15.23

All         34.01   38.83   27.16  100.00
           100.00  100.00  100.00  100.00
            34.01   38.83   27.16  100.00

Pearson Chi-Square = 2.627, DF = 4, P-Value = 0.622
Likelihood Ratio Chi-Square = 2.654, DF = 4, P-Value = 0.617
```

Table C.61: Chi-Square test – Company structure and LSS & environmental employees working together on improvement projects

```
Tabulated statistics: Structure, Green 7 Waste Response
Pearson Chi-Square = 5.330, DF = 2, P-Value = 0.070
Likelihood Ratio Chi-Square = 5.140, DF = 2, P-Value = 0.077

Tabulated statistics: Structure 1, Green 5S Response
Pearson Chi-Square = 0.835, DF = 2, P-Value = 0.659
Likelihood Ratio Chi-Square = 0.819, DF = 2, P-Value = 0.664

Tabulated statistics: Structure 2, Green VSM Response
Pearson Chi-Square = 3.958, DF = 2, P-Value = 0.138
Likelihood Ratio Chi-Square = 3.962, DF = 2, P-Value = 0.138

Tabulated statistics: Structure 3, Green Kaizen Response
Pearson Chi-Square = 1.274, DF = 2, P-Value = 0.529
Likelihood Ratio Chi-Square = 1.272, DF = 2, P-Value = 0.530

Tabulated statistics: Structure 4, Green Process Mapping
Pearson Chi-Square = 0.822, DF = 2, P-Value = 0.663
Likelihood Ratio Chi-Square = 0.819, DF = 2, P-Value = 0.664
```

Table C.62: Chi-Square test – Company structure and green LSS Tools

```
Using frequencies in Observed_1


Rows: Structure_1   Columns: Green 7 Waste Response_1

                 0       1     All

LTD          14.29   85.71  100.00
             52.78   72.61   68.91
              9.84   59.07   68.91

ST/PTS       28.33   71.67  100.00
             47.22   27.39   31.09
              8.81   22.28   31.09

All          18.65   81.35  100.00
            100.00  100.00  100.00
             18.65   81.35  100.00

Pearson Chi-Square = 5.377, DF = 1, P-Value = 0.020
Likelihood Ratio Chi-Square = 5.104, DF = 1, P-Value = 0.024
```

Table C.63: Chi-Square test – Company structure and green 7 wastes

C.4 LSS Role Type Tests

```
Kruskal-Wallis Test on LSS User Response

LSS Role      N  Median  Ave Rank      Z
BB/MBB/TR   202   5.000     228.6   4.40
GB/PR       101   4.000     179.6  -2.32
YB/CH/TM    102   4.000     175.4  -2.76
Overall     405             203.0

H = 19.41  DF = 2  P = 0.001
H = 20.58  DF = 2  P = 0.001  (adjusted for ties)
```

Table C.64: Kruskal-Wallis Test – LSS role type and LSS experience

```
              N  Median
BB/MBB/TR   202  5.0000
GB/LP       101  4.0000


Point estimate for ETA1-ETA2 is 1.0000
95.0 Percent CI for ETA1-ETA2 is (0.0001,0.9999)
W = 33260.0
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.0002
The test is significant at 0.0001 (adjusted for ties)

 N  Median
BB/MBB/TR   202  5.0000
CH/YB/TM    102  4.0000


Point estimate for ETA1-ETA2 is 1.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0003,1.0001)
W = 33430.0
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.0001
The test is significant at 0.0001 (adjusted for ties)

 N  Median
GB/LP     101  4.0000
CH/YB/TM  102  4.0000


Point estimate for ETA1-ETA2 is -0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0003,0.0001)
W = 10495.5
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.3223
The test is significant at 0.3180 (adjusted for ties)
```

Table C.65 Mann Whitney Test - LSS role type and duration of LSS experience

```
Kruskal-Wallis Test on LSS Benefits Response

LSS Role      N  Median  Ave Rank      Z
BB/MBB/TR   201   4.000     210.8   1.79
GB/PR       100   4.000     189.3  -1.12
YB/CH/TM     99   4.000     190.9  -0.96
Overall     400             200.5

H = 3.22  DF = 2  P = 0.200
H = 4.09  DF = 2  P = 0.129  (adjusted for ties)
```

Table C.66: Kruskal-Wallis test - LSS role type and LSS benefits

```
Tabulated statistics: LSS Role, Management Commitment Response
Pearson Chi-Square = 0.758, DF = 2, P-Value = 0.685
Likelihood Ratio Chi-Square = 0.774, DF = 2, P-Value = 0.679

Tabulated statistics: LSS Role_1, Sustainability Response_1
Pearson Chi-Square = 2.233, DF = 2, P-Value = 0.327
Likelihood Ratio Chi-Square = 2.239, DF = 2, P-Value = 0.326

Tabulated statistics: LSS Role_2, Stakeholder Involve Response_2
Pearson Chi-Square = 1.343, DF = 2, P-Value = 0.511
Likelihood Ratio Chi-Square = 1.346, DF = 2, P-Value = 0.510

Tabulated statistics: LSS Role_3, History failed Projects_3
Pearson Chi-Square = 0.693, DF = 2, P-Value = 0.707
Likelihood Ratio Chi-Square = 0.689, DF = 2, P-Value = 0.709

Tabulated statistics: LSS Role_4, Team LSS Knowledge_4
Pearson Chi-Square = 3.957, DF = 2, P-Value = 0.138
Likelihood Ratio Chi-Square = 3.955, DF = 2, P-Value = 0.138
```

Table C.67: Chi-Square test – LSS role and biggest concerns over deployment of LSS

```
Kruskal-Wallis Test on LSS User Response

LSS Role      N  Median  Ave Rank      Z
BB/MBB/TR   169   3.000     155.0  -1.22
GB/PR        71   3.000     168.0   0.72
YB/CH/TM     81   3.000     167.3   0.71
Overall     321             161.0

H = 1.48  DF = 2  P = 0.477
H = 1.59  DF = 2  P = 0.451  (adjusted for ties)
```

Table C.68: Kruskal-Wallis Test - LSS role and environmental benefits of LSS

```
Kruskal-Wallis Test on LSS User Response

LSS Role      N  Median  Ave Rank      Z
BB/MBB/TR   161   1.000     136.9  -1.95
GB/PR        58   1.000     146.6   0.12
YB/CH/TM     71   2.000     164.0   2.14
Overall     290             145.5

H = 5.18  DF = 2  P = 0.075
H = 7.09  DF = 2  P = 0.029  (adjusted for ties)
```

Table C.69: Kruskal-Wallis test - LSS Role and environmental negatives from using LSS

```
                N  Median
CH/YB/TM       71  2.0000
BB/MBB/TR     161  1.0000


Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0001,0.0001)
W = 9360.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0209
The test is significant at 0.0069 (adjusted for ties)

                N  Median
GB/LP          58  1.0000
BB/MBB/TR     161  1.0000


Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (0.0001,0.0001)
W = 6675.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.4766
The test is significant at 0.3868 (adjusted for ties)

                N  Median
CH/YB/TM       71  2.0000
BB/MBB/TR     161  1.0000


Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0001,0.0001)
W = 9360.0
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.0105
The test is significant at 0.0035 (adjusted for ties)
```

Table C.70: Mann-Witney test - LSS Role and environmental negatives from using LSS

```
Tabulated statistics: LSS Role, Green Lean Response
Pearson Chi-Square = 1.318, DF = 2, P-Value = 0.517
Likelihood Ratio Chi-Square = 1.327, DF = 2, P-Value = 0.515

Tabulated statistics: LSS Role_1, Green Sigma Response_1
Pearson Chi-Square = 2.512, DF = 2, P-Value = 0.285
Likelihood Ratio Chi-Square = 2.822, DF = 2, P-Value = 0.244

Tabulated statistics: LSS Role_2, Green Lean Six Sigma Response_2
Pearson Chi-Square = 1.447, DF = 2, P-Value = 0.485
Likelihood Ratio Chi-Square = 1.456, DF = 2, P-Value = 0.483

Tabulated statistics: LSS Role_3, Non of the above_3
Pearson Chi-Square = 0.604, DF = 2, P-Value = 0.739
Likelihood Ratio Chi-Square = 0.605, DF = 2, P-Value = 0.739
```

Table C.71: Chi Square Tests – LSS Role and Awareness of Green versions of LSS

```
Using frequencies in Observed

Rows: LSS Role   Columns: LSS EMS Response

                    0       1       2     All

BB/MBB/TR       16.34   51.49   32.18  100.00
                61.11   47.93   48.51   49.88
                 8.15   25.68   16.05   49.88

CH/YB/TM         9.80   59.80   30.39  100.00
                18.52   28.11   23.13   25.19
                 2.47   15.06    7.65   25.19

GB/LP           10.89   51.49   37.62  100.00
                20.37   23.96   28.36   24.94
                 2.72   12.84    9.38   24.94

All             13.33   53.58   33.09  100.00
               100.00  100.00  100.00  100.00
                13.33   53.58   33.09  100.00

Pearson Chi-Square = 4.659, DF = 4, P-Value = 0.324
Likelihood Ratio Chi-Square = 4.651, DF = 4, P-Value = 0.325
```

Table C.72: Chi Square Test – LSS role and value of combining LSS and environmental management

```
Using frequencies in Observed

Rows: LSS Role   Columns: LSS enhance EMS Response

                    0       1       2     All

BB/MBB/TR        6.44   64.36   29.21  100.00
                39.39   52.21   47.97   49.88
                 3.21   32.10   14.57   49.88

CH/YB/TM         8.82   59.80   31.37  100.00
                27.27   24.50   26.02   25.19
                 2.22   15.06    7.90   25.19

GB/LP           10.89   57.43   31.68  100.00
                33.33   23.29   26.02   24.94
                 2.72   14.32    7.90   24.94

All              8.15   61.48   30.37  100.00
               100.00  100.00  100.00  100.00
                 8.15   61.48   30.37  100.00

Cell Contents:      % of Row
                    % of Column
                    % of Total


Pearson Chi-Square = 2.486, DF = 4, P-Value = 0.647
Likelihood Ratio Chi-Square = 2.454, DF = 4, P-Value = 0.653
```

Table C.73: Chi Square Test – LSS Role and LSS enhancing environmental practices

```
Rows: LSS Role   Columns: Impact of E-Legislation Respons

                   0       1       2     All

BB/MBB/TR      36.14   50.00   13.86  100.00
               60.83   47.42   38.89   49.88
               18.02   24.94    6.91   49.88

CH/YB/TM       18.63   64.71   16.67  100.00
               15.83   30.99   23.61   25.19
                4.69   16.30    4.20   25.19

GB/LP          27.72   45.54   26.73  100.00
               23.33   21.60   37.50   24.94
                6.91   11.36    6.67   24.94

All            29.63   52.59   17.78  100.00
              100.00  100.00  100.00  100.00
               29.63   52.59   17.78  100.00

Pearson Chi-Square = 17.607, DF = 4, P-Value = 0.001
Likelihood Ratio Chi-Square = 17.442, DF = 4, P-Value = 0.002
```

Table C.74: Chi Square Test – LSS role and impact of environmental legislation

```
Kruskal-Wallis Test on LSS User Response

LSS Role      N  Median  Ave Rank      Z
BB/MBB/TR   202   4.000     206.2   0.56
GB/PR       101   4.000     207.0   0.40
YB/CH/TM    102   4.000     192.6  -1.04
Overall     405             203.0

H = 1.08  DF = 2  P = 0.581
H = 1.26  DF = 2  P = 0.532  (adjusted for ties)
```

Table C.75: Kruskal-Wallis Test – LSS Role and personal concern over the environment

```
Tabulated statistics: LSS Role, General Waste land/sea Response
Pearson Chi-Square = 0.309, DF = 2, P-Value = 0.857
Likelihood Ratio Chi-Square = 0.309, DF = 2, P-Value = 0.857

Tabulated statistics: LSS Role_1, Air Qualit yResponse
Pearson Chi-Square = 0.145, DF = 2, P-Value = 0.930
Likelihood Ratio Chi-Square = 0.145, DF = 2, P-Value = 0.930

Tabulated statistics: LSS Role_2, Water Quality Response
Pearson Chi-Square = 2.113, DF = 2, P-Value = 0.348
Likelihood Ratio Chi-Square = 2.146, DF = 2, P-Value = 0.342

Tabulated statistics: LSS Role_3, Energy Production Response
Pearson Chi-Square = 0.240, DF = 2, P-Value = 0.887
Likelihood Ratio Chi-Square = 0.240, DF = 2, P-Value = 0.887

Tabulated statistics: LSS Role_4, People, animal health Response
Pearson Chi-Square = 1.848, DF = 2, P-Value = 0.397
Likelihood Ratio Chi-Square = 1.852, DF = 2, P-Value = 0.396
```

Table C.76: Chi-Square test – LSS role and types of environmental concerns

```
Tabulated statistics: LSS Role, Green 7 Waste Response
Pearson Chi-Square = 0.391, DF = 2, P-Value = 0.822
Likelihood Ratio Chi-Square = 0.396, DF = 2, P-Value = 0.820

Tabulated statistics: LSS Role_1, Green 5S Response
Pearson Chi-Square = 0.388, DF = 2, P-Value = 0.824
Likelihood Ratio Chi-Square = 0.387, DF = 2, P-Value = 0.824

Tabulated statistics: LSS Role_2, Green VSM Response
Pearson Chi-Square = 4.360, DF = 2, P-Value = 0.113
Likelihood Ratio Chi-Square = 4.369, DF = 2, P-Value = 0.113

Tabulated statistics: LSS Role_3, Green Kaizen Response
Pearson Chi-Square = 0.010, DF = 2, P-Value = 0.995
Likelihood Ratio Chi-Square = 0.010, DF = 2, P-Value = 0.995

Tabulated statistics: LSS Role_4, Green Process Mapping
Pearson Chi-Square = 1.960, DF = 2, P-Value = 0.375
Likelihood Ratio Chi-Square = 1.952, DF = 2, P-Value = 0.377
```

Table C.77: Chi-Square Test – LSS Role and "Green" LSS Tools

C.5 LSS Experience Tests

```
Kruskal-Wallis Test on LSS Benefits Response

LSS Experiance      N  Median  Ave Rank      Z
0-2 Years          96   4.000     179.6  -2.84
10 Years +        110   4.000     211.9   0.14
2-5 Years         125   4.000     199.8  -1.17
5-10 Years         89   4.000     257.1   4.08
Overall           420             210.5

H = 20.30  DF = 3  P = 0.000
H = 25.66  DF = 3  P = 0.000  (adjusted for ties)
```

Table C.78: Kruskal-Wallis test - LSS experience and LSS benefits

```
Source   DF       SS     MS     F      P
Factor    3   12.064  4.021  7.77  0.000
Error   416  215.165  0.517
Total   419  227.229

S = 0.7192   R-Sq = 5.31%   R-Sq(adj) = 4.63%


                                 Individual 95% CIs For Mean Based on
                                 Pooled StDev
Level         N    Mean   StDev  ---------+---------+---------+---------+
0-2 Years    96  3.5625  0.7372  (------*------)
2-5 Years   125  3.6960  0.6866         (------*-----)
5-10 Years   89  4.0562  0.6633                          (-------*------)
10+ Years   110  3.7545  0.7803            (------*-----)
                                 ---------+---------+---------+---------+
                                       3.60      3.80      4.00      4.20
```

Table C.79: One way ANOVA – LSS experience and LSS benefits

```
Using frequencies in Observed_4

Rows: LSS Experience_4   Columns: Team LSS Knowledge_4

                  0        1      All

0-2 Years      51.02    48.98   100.00
               13.30    33.33    18.85
                9.62     9.23    18.85

10+ Years      80.00    20.00   100.00
               27.66    18.06    25.00
               20.00     5.00    25.00

2-5 Years      71.43    28.57   100.00
               29.26    30.56    29.62
               21.15     8.46    29.62

5-10 Years     81.16    18.84   100.00
               29.79    18.06    26.54
               21.54     5.00    26.54

All            72.31    27.69   100.00
              100.00   100.00   100.00
               72.31    27.69   100.00

Cell Contents:      % of Row
                    % of Column
                    % of Total


Pearson Chi-Square = 15.740, DF = 3, P-Value = 0.001
Likelihood Ratio Chi-Square = 14.940, DF = 3, P-Value = 0.002
```

Table C.80: Chi Square Test – LSS Experience and team's knowledge of LSS

```
Kruskal-Wallis Test on LSS User Response

LSS Experience     N  Median  Ave Rank      Z
0-2 Years         74   3.000     167.8  -0.02
2-5 Years         96   3.000     155.7  -1.47
5-10 Years        72   4.000     195.3   2.70
10 Years +        93   3.000     159.7  -0.97
Overall          335             168.0

H = 7.94  DF = 3  P = 0.047
H = 8.55  DF = 3  P = 0.036  (adjusted for ties)
```

Table C.81: Kruskal-Wallis Test – LSS Experience and Environmental Benefits of LSS

```
            Mann-Whitney Test and CI: 5-10 Years, 0-2 Years
             N  Median
5-10 Years  72  4.0000
0-2 Years   74  3.0000


Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0001,1.0002)
W = 5709.0
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.0515
The test is significant at 0.0447 (adjusted for ties)

             N  Median
5-10 Years  72  4.0000
2-5 Years   96  3.0000


Point estimate for ETA1-ETA2 is -0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.0001,1.0000)
W = 6923.0
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.0036
The test is significant at 0.0026 (adjusted for ties)

             N  Median
5-10 Years  72  4.0000
10+ Years   93  3.0000


Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (0.0002,0.9999)
W = 6683.5
Test of ETA1 = ETA2 vs ETA1 > ETA2 is significant at 0.0101
The test is significant at 0.0078 (adjusted for ties)
```

Table C.82: Mann-Whitney Test – LSS Experience and environmental benefits

```
Kruskal-Wallis Test on LSS User Response

LSS Experiance    N  Median  Ave Rank      Z
0-2 Years        63   1.000     160.5   0.81
10 Years +       89   1.000     148.3  -0.54
2-5 Years        82   1.000     161.8   1.13
5-10 Years       70   1.000     139.7  -1.39
Overall         304             152.5

H = 3.15  DF = 3  P = 0.369
H = 4.30  DF = 3  P = 0.231  (adjusted for ties)
```

Table C.83: Kruskal-Wallis test – LSS experience and environmental negatives from using LSS

Using frequencies in Observed

Rows: LSS Experiance Columns: Green Lean Response

	0	1	All
0-2 Years	82.18	17.82	100.00
	24.78	19.57	23.65
	19.44	4.22	23.65
10+ Years	78.38	21.62	100.00
	25.97	26.09	26.00
	20.37	5.62	26.00
2-5 Years	84.80	15.20	100.00
	31.64	20.65	29.27
	24.82	4.45	29.27
5-10 Years	65.56	34.44	100.00
	17.61	33.70	21.08
	13.82	7.26	21.08
All	78.45	21.55	100.00
	100.00	100.00	100.00
	78.45	21.55	100.00

Cell Contents: % of Row
% of Column
% of Total

Pearson Chi-Square = 12.665, DF = 3, P-Value = 0.005

Table C.84: Chi Square Test - LSS Experience and "Green Lean" Awareness

```
Using frequencies in Observed_2


Rows: LSS Experiance_2   Columns: Green Lean Six Sigma Response_2

                      0        1      All

0-2 Years         95.05     4.95   100.00
                  25.81     9.09    23.65
                  22.48     1.17    23.65

10+ Years         87.39    12.61   100.00
                  26.08    25.45    26.00
                  22.72     3.28    26.00

2-5 Years         88.00    12.00   100.00
                  29.57    27.27    29.27
                  25.76     3.51    29.27

5-10 Years        76.67    23.33   100.00
                  18.55    38.18    21.08
                  16.16     4.92    21.08

All               87.12    12.88   100.00
                 100.00   100.00   100.00
                  87.12    12.88   100.00

Cell Contents:        % of Row
                      % of Column
                      % of Total


Pearson Chi-Square = 14.517, DF = 3, P-Value = 0.002
```

Table C.85: Chi Square Test - LSS Experience and Green Lean Six Sigma

Using frequencies in Observed_3

Rows: LSS Experiance_3   Columns: Non of the above_3

	0	1	All
0-2 Years	22.77	77.23	100.00
	16.20	27.37	23.65
	5.39	18.27	23.65
10+ Years	33.33	66.67	100.00
	26.06	25.96	26.00
	8.67	17.33	26.00
2-5 Years	30.40	69.60	100.00
	26.76	30.53	29.27
	8.90	20.37	29.27
5-10 Years	48.89	51.11	100.00
	30.99	16.14	21.08
	10.30	10.77	21.08
All	33.26	66.74	100.00
	100.00	100.00	100.00
	33.26	66.74	100.00

Cell Contents: % of Row
% of Column
% of Total

Pearson Chi-Square = 15.370, DF = 3, P-Value = 0.002

Table C.86: Chi Square test - LSS experience and none of the Green LSS approaches

Using frequencies in Observed

Rows: LSS Experiance   Columns: LSS EMS Response

	0	1	2	All
0-2 Years	11.88	49.50	38.61	100.00
	21.82	21.65	27.66	23.65
	2.81	11.71	9.13	23.65
10+ Years	12.61	57.66	29.73	100.00
	25.45	27.71	23.40	26.00
	3.28	14.99	7.73	26.00
2-5 Years	12.80	48.80	38.40	100.00
	29.09	26.41	34.04	29.27
	3.75	14.29	11.24	29.27
5-10 Years	14.44	62.22	23.33	100.00
	23.64	24.24	14.89	21.08
	3.04	13.11	4.92	21.08
All	12.88	54.10	33.02	100.00
	100.00	100.00	100.00	100.00
	12.88	54.10	33.02	100.00

Cell Contents: % of Row
% of Column
% of Total

Pearson Chi-Square = 7.631, DF = 6, P-Value = 0.266
Likelihood Ratio Chi-Square = 7.806, DF = 6, P-Value = 0.253

Table C.87: Chi Square Test – LSS experience and value of combined LSS and environmental management

```
Using frequencies in Observed


Rows: LSS Experiance   Columns: LSS enhance EMS Response

                   0       1       2     All

0-2 Years       7.92   52.48   39.60  100.00
               24.24   20.15   30.53   23.65
                1.87   12.41    9.37   23.65

10+ Years       6.31   64.86   28.83  100.00
               21.21   27.38   24.43   26.00
                1.64   16.86    7.49   26.00

2-5 Years       9.60   57.60   32.80  100.00
               36.36   27.38   31.30   29.27
                2.81   16.86    9.60   29.27

5-10 Years      6.67   73.33   20.00  100.00
               18.18   25.10   13.74   21.08
                1.41   15.46    4.22   21.08

All             7.73   61.59   30.68  100.00
              100.00  100.00  100.00  100.00
                7.73   61.59   30.68  100.00

Cell Contents:      % of Row
                    % of Column
                    % of Total


Pearson Chi-Square = 11.162, DF = 6, P-Value = 0.083
Likelihood Ratio Chi-Square = 11.357, DF = 6, P-Value = 0.078
```

Table C.88: Chi Square Test – LSS experience and enhancement of current environmental management practices

Using frequencies in Observed

Rows: LSS Experiance   Columns: Impact of E-Legislation Respons

	0	1	2	All
0-2 Years	14.85	65.35	19.80	100.00
	11.72	29.60	26.32	23.65
	3.51	15.46	4.68	23.65
10+ Years	31.53	51.35	17.12	100.00
	27.34	25.56	25.00	26.00
	8.20	13.35	4.45	26.00
2-5 Years	32.80	44.80	22.40	100.00
	32.03	25.11	36.84	29.27
	9.60	13.11	6.56	29.27
5-10 Years	41.11	48.89	10.00	100.00
	28.91	19.73	11.84	21.08
	8.67	10.30	2.11	21.08
All	29.98	52.22	17.80	100.00
	100.00	100.00	100.00	100.00
	29.98	52.22	17.80	100.00

Cell Contents: % of Row
% of Column
% of Total

Pearson Chi-Square = 21.528, DF = 6, P-Value = 0.001
Likelihood Ratio Chi-Square = 23.188, DF = 6, P-Value = 0.001

Table C.89: Chi Square Test – LSS experience and impact of environmental legislation

Using frequencies in Observed 2

Rows: LSS Experiance_2 Columns: Green VSM Response

	0	1	All
0-2 Years	52.48	47.52	100.00
	29.94	19.20	23.65
	12.41	11.24	23.65
10+ Years	39.64	60.36	100.00
	24.86	26.80	26.00
	10.30	15.69	26.00
2-5 Years	38.40	61.60	100.00
	27.12	30.80	29.27
	11.24	18.03	29.27
5-10 Years	35.56	64.44	100.00
	18.08	23.20	21.08
	7.49	13.58	21.08
All	41.45	58.55	100.00
	100.00	100.00	100.00
	41.45	58.55	100.00

Cell Contents: % of Row
% of Column
% of Total

Pearson Chi-Square = 6.976, DF = 3, P-Value = 0.073
Likelihood Ratio Chi-Square = 6.915, DF = 3, P-Value = 0.075

Table C.90: Chi Square Test – LSS experience and green VSM tool

```
Using frequencies in Observed 3


Rows: LSS Experiance_3   Columns: Green Kaizen Response

                    0       1     All

0-2 Years       56.44   43.56  100.00
                30.81   18.18   23.65
                13.35   10.30   23.65

10+ Years       39.64   60.36  100.00
                23.78   27.69   26.00
                10.30   15.69   26.00

2-5 Years       42.40   57.60  100.00
                28.65   29.75   29.27
                12.41   16.86   29.27

5-10 Years      34.44   65.56  100.00
                16.76   24.38   21.08
                 7.26   13.82   21.08

All             43.33   56.67  100.00
               100.00  100.00  100.00
                43.33   56.67  100.00

Cell Contents:       % of Row
                     % of Column
                     % of Total


Pearson Chi-Square = 10.618, DF = 3, P-Value = 0.014
Likelihood Ratio Chi-Square = 10.603, DF = 3, P-Value = 0.014
```

Table C.91: Chi Square Test – LSS experience and green Kaizen tool

```
Using frequencies in Observed 4


Rows: LSS Experiance_4   Columns: Green Process Mapping

                      0       1     All

0-2 Years         55.45   44.55  100.00
                  30.43   18.52   23.65
                  13.11   10.54   23.65

10+ Years         38.74   61.26  100.00
                  23.37   27.98   26.00
                  10.07   15.93   26.00

2-5 Years         44.00   56.00  100.00
                  29.89   28.81   29.27
                  12.88   16.39   29.27

5-10 Years        33.33   66.67  100.00
                  16.30   24.69   21.08
                   7.03   14.05   21.08

All               43.09   56.91  100.00
                 100.00  100.00  100.00
                  43.09   56.91  100.00

Cell Contents:      % of Row
                    % of Column
                    % of Total


Pearson Chi-Square = 10.680, DF = 3, P-Value = 0.014
Likelihood Ratio Chi-Square = 10.700, DF = 3, P-Value = 0.013
```

Table C.92: Chi Square Test – LSS experience and Green Process Mapping tool

Appendix D: BAA Glasgow Environmental 5S Audit

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BAA Glasgow Environmental 5S Audit

Welcome to this audit. It should take about 5-10 minutes to complete.

The audit follows the conventional 5S process but includes environmental controls and principles

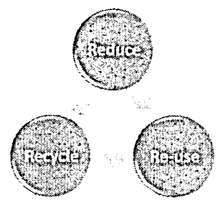


Figure D.1: Environmental 5S Introduction

Environmental 5S Aims

- Enhance (not replace) the well established and proven 5S process and increase its sustainability in the workplace
- Identify and consider environmental issues (Aspects and Impacts) within the workplace as part of the 5S programme
- Use less material and energy such as water, chemicals, electricity and subsequently reduce emissions
- Reduce the overall environmental impact within the workplace to meet existing or forthcoming legislation
- Improve overall internal and external quality including reducing errors, defects, rework and scrap

Please complete the following for your department or function. Your time is appreciated

If you have any problems please contact James Marsh

Tel: 0780 6505859 Or Email: jamarsh8@my.shu.ac.uk

Figure D.2: Environmental 5S Aims

Basic Employee Information

Employee Gender

--Click Here--

- *Male*
- *Female*

Q1

Employee Age

--Click Here--

- *Under 20*
- *20-29*
- *30-39*
- *40-49*
- *50-59*
- *60 +*

Q2

Time employed (years) by BAA Glasgow

--Click Here--

- *1 <*
- *1-2*
- *3-4*
- *5-9*
- *10 +*
- *N/A e.g not company employee*

Q3

Figure D.3: Basic Employee Information

BAA Glasgow Organisational Profile

Your Main Department / Function

--Click Here--

- *Airport Senior Management*
- *Airside Operations*
- *Business Support Services*
- *Customer Service*
- *Development*
- *Finance*
- *Fire Service*
- *H&S*
- *Maintenance*
- *Property/Retail*
- *Security*

Q4

Your Specific Area Assessed

--Click Here--

- *Airfield Operations Offices*
- *Airfield Operations Tower*
- *Airfield Workshop*
- *Arran Court*
- *Emergency Services Hanger*
- *Erskine Court*
- *Facilities Maintenance Offices*
- *Fire Station*
- *HR Offices*
- *Logistics Store*
- *Motor Transport*
- *Rooftop Office Complex*
- *Whitehouse Offices*

Q5

Your Organisation Level at BAA Glasgow

--Click Here--

-Director

-Manager

-Team Leader

-Operational Staff

-Support Staff

-External to BAA

Q6

Environmental 5S Assessment date, please specify in (DD/MM/YYYY)

Q7

Figure D.4:: BAA Glasgow Organisational Profile

Employee 5S Experience Questions

Have you received 5S Training?

--Click Here--

- Yes at BAA Glasgow
- Yes but not at BAA Glasgow
- No but would like 5S training
- No but i'm aware of 5S principles
- No

Q8

How long have you been using 5S?

--Click Here--

- I have never used 5S
- 6 months or less
- 7-12 Months
- 1-2 Years
- 2-5 Years
- 5 Years +

Q9

Please select your 5S Roles

- Trainer
- Practitioner
- Implementor
- Champion
- Auditor
- External Assessor/Consultant
- I have responsibilities for an Area
- I have no 5S role

Q10

What type of benefits have you achieved from using 5S, please tick those that apply?

- Improved quality (e.g less defects, less variation)
- Lower costs (e.g.quantified reductions or benefits to the business)
- Improved delivery (e.g customer lead-times reduced)
- Cultural benefits (e.g. more motivated workforce)
- Environmental / Safety (less spills, emissions, leaks, accidents etc)
- None

Q11

Figure D.5: Employee 5S Experience Questions

General Environmental Questions

Do you consider a combined approach of 5S and Environmental Management of value to your organisation?

Q12
--Click Here--
- *Yes*
- *No*
- *Not considered this before*

How much are you personally concerned about the environment?

Q13
--Click Here--
- *Extremely*
- *Highly*
- *Sometimes*
- *Slightly*
- *Never*

Are you concerned about the impact of increasing environmental legislation and targets on your organisation?

Q14
--Click Here--
- *Yes*
- *No*
- *Not considered this before*

Figure D.6: General Environmental Questions

1. Sort Phase (organisation) - "Separate the essential from the non-essential"

Implementation tips and things to look for:-

- In the work area identify any unnecessary hazards and wastes such as energy, chemical waste, rubbish and used consumables.
- The Green tagging methodology should be incorporated into the work area to help sort environmental wastes or hazardous materials
- Environmental quarantine area should be clearly defined and be use and known by all team members.
- Clarify what constitutes a waste and what does not discuss with the team at 5S review sessions. these could be placed on a list in the work area or photos could be used to help speed up the Sort phase.
- Use of Lean Six Sigma tools such as VSM and 7 wastes to help identify environmentally negative non-value added (NVA) wastes.
- Have team members or others left personal items of an environmentally hazardous or wasteful nature within designated areas?

Key Benefits:- 1. Reduction in NVA environmental waste 2. Begins to create a clear transparent work area and associated processes 3. Improve Safety

Sort Audit

		Never	*Rarely*	*Half the time*	*Mostly*	*Always*
Q15a	Is there no unnecessary environmental hazards or wastes visible in the work area?	○	○	○	○	○
Q15b	Are environmentally hazardous or waste items in the work area Green tagged, registered and kept up to date?	○	○	○	○	○
Q15c	Have items classed as environmentally hazardous or wasteful been placed in a designated quarantine area?	○	○	○	○	○
Q15d	Have environmentally friendly alternatives have been identified and implemented?	○	○	○	○	○
Q15e	Are green tagged items being disposed of in an appropriate and environmentally safe manner?	○	○	○	○	○

Please add any positive or negative comments you may have for the Sort phase this period.

Q16

Figure D.7: Environmental 5S Audit Sort Phase

2. Straighten and Set Location Phase (orderliness) - "A place for everything and everything in its place"

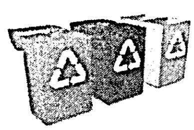
Implementation tips and things to look for:-

- Does the team have operating procedures for waste processes?
- Hazardous items could be chemicals, printer inks, light bulbs, bi-products
- Wasteful items could be light switches, plug sockets, computers, and machines left in the "on" position.
- The team should install and set energy saving devices such as thermostats on radiators and water.
- The team regularly considers opportunities to reduce levels of usage and and increase recycling
- Have waste streams, products, consumables etc identified as recyclable?
- Team considers the 3 R's, reduce, re-use, recycle as part of daily routine
- Look for external sorting / filtering of waste / off-site activities
- Is it visual and clear to all within the work area?

Key Benefits:- 1. Clear visual standards 2. Making abnormality clear to all team members 3. Reduced energy and valuable resources consumption

Straighten and Set Location Audit

		Never	*Rarely*	*Half The time*	*Mostly*	*Always*
Q17a	Within the work area are all environmentally hazardous or wasteful items clearly labelled and visible?	○	○	○	○	○
Q17b	Have all environmentally hazardous or wasteful items been stored in appropriate (size and type) containers or storage devices?	○	○	○	○	○
Q17c	Have the correct recycling waste stream bins for different types of waste (paper, metals, compostable items, liquids etc) being used?	○	○	○	○	○
Q17d	Does the work area use the appropriate methods for disposing of wastes and environmental hazards?	○	○	○	○	○
Q17e	Are appropriate risk management of environmental hazards and wastes in place? (E.g. Spill kits, Personal Protective Equipment, alarms etc)	○	○	○	○	○



Please add any positive or negative comments you may have for the Straighten phase this period.

Q18

Figure D.8: Environmental 5S Audit Straighten and Set Phase

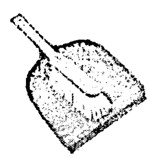
Implementation tips and things to look for:-

- Within the work area do processes exist for checking the impact on the environment?
- Are there any metrics/indicators that encourage the sweep phase?
- Do the 5S team monitor sweep processes on a regular basis at set intervals?
- Within the work area check the floors for leaks and spills, what is the air quality like, is it clear of fumes, dust and odours?
- Is there evidense of obstructions to vents, drains and filters in the work area?

Key Benefits:- 1. Safe clean working environment 2. Developing ownership within the work area 3. Reduced probability environmental defects

Sweep and Shine Audit

		Never	*Rarely*	*Half the Time*	*Mostly*	*Always*
Q19a	Has the team defined and agreed the roles and responsibilities of Environmental Sweep check-sheets and is it operational and topical?	◯	◯	◯	◯	◯
Q19b	Are environmental wastes placed in the correct waste bins?	◯	◯	◯	◯	◯
Q19c	Is a Environmental sweep conducted at set intervals (E.g. daily or weekly) and reviews in place?	◯	◯	◯	◯	◯
Q19d	Is the area cleaned of any environmental hazards or wastes on a daily basis with no evidence of spills or leaks?	◯	◯	◯	◯	◯
Q19e	Does the team use environmentally safe cleaning materials used where feasible within the work area?	◯	◯	◯	◯	◯



Please add any <u>positive or negative</u> comments you may have for the Sweeping phase this period.

Q20

Figure D.9: Environmental 5S Audit Shine and Sweep Phase

4. Standardise Phase (Adherence) - "Ensure that we don't do what we always did"

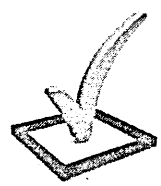
Implementation tips and things to look for:-

- Pro-active and re-active solutions should be sought that prevent waste and also stop the waste having an impact.
- Work area should use where possible energy saving devices (e.g. motion sensors for lighting, energy saving light bulbs, standby saving devices, water saving toilets etc)
- In the work area there should be usage charts for chemicals or other environmentally unfriendly or hazardous items
- There should be physical indicators in the work area these could include energy usage, water usage, air emissions, water pollutants, landfill wastes, other hazardous wastes and scrap / rework levels

Key Benefits:- 1. Stable processes as a foundation for improvement. 2. Clear environmental indicators understood by team members.

Standardise Audit

	Never	*Rarely*	*Half the Time*	*Mostly*	*Always*
Q21a Does the work area take positive measures to identify, contain and avoid environmental risks and wastes?					
Q21b Does the work area show clear and concise environmental indicators and are correct levels demonstrated?					
Q21c Does the work area contain all relevant documents regarding environmental risks or wastes and is it clearly identified and located?					
Q21d Do positional markers exist on walls and floors in the work area for environmental risks or wastes?					
Q21e Have all alarms (fire, air quality etc) systems been tested within the recommended dates?					



Please add any positive or negative comments you may have for the Standardising phase this period.

Q22

Figure D.10: Environmental 5S Audit Standardise Phase

5. Sustain Phase (self discipline) - "Making Environmental 5S part of everyday life to maintain improvement"

Implementation tips and things to look for:-

- Reviews of the Environmental 5S audit are organised and conducted on a regular and agreed frequency
- Is it clear where waste is coming from? - Streams, areas, processes, service and products? Are people within the team aware?
- What is the general feeling for "environmental" issues within the group?
- Suggestion schemes in place within the work area for delivering effective environmental solutions.
- A visual control board with all relevant environmental 5S information is set up in the work area and is kept topical by a nominated team member
- All team members should be trained in conventional 5S and have awareness of what environmental 5S is, flag this up if this does not occur
- Is the Environmental 5S process aligned to the overall business strategy - is it visible to all?
- A reward and recognition scheme in place for identification of environmental innovations and translation to best practice to other areas?

Key Benefits:- 1. Sustaining improvement and an awareness of visual control. 2. Recognition for innovation and idea generation

Sustaining Audit

	Never	*Rarely*	*Half the Time*	*Mostly*	*Always*
Q23a Does the working area comply with the Environmental 5S benchmark photo or check-sheet 100%?	○	○	○	○	○
Q23b Have all previous actions from Environmental 5S audits completed and cleared?	○	○	○	○	○
Q23c Do the reviews for the Environmental 5S audit take place in an open and transparent manner ?	○	○	○	○	○
Q23d Has the scores for the Environmental 5S audit been made visible to all team members?	○	○	○	○	○
Q23e Have all team members had training in conventional 5S and have basic awareness of the Environmental 5S process?	○	○	○	○	○

Please add any positive or negative comments you may have for the Sustaining phase this period.

Q24

Figure D.11: Environmental 5S Audit Sustain Phase

Thanks, you have completed the BAA Environmental 5S assessment

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If you have any problems please contact James Marsh

Tel:0780 6505859 or Email:jamarsh8@my.shu.ac.uk

Figure D.12: Environmental 5S Audit Completion Page

Appendix E: BAA Glasgow Results

Base	100.0%
Employee Gender	
Male	75.0%
Female	25.0%

Table E.1: BAA Glasgow Gender

Base	100.0%
Possible Ages of Respondent	
Under 20	-
20-29	11.1%
30-39	22.2%
40-49	44.4%
50-59	19.4%
60 +	2.8%

Table E.2: BAA Glasgow Respondents Age

Base	100.0%
Time employed (years) by BAA Glasgow	
1 <	5.6%
1-2	25.0%
3-4	13.9%
5-9	8.3%
10 +	44.4%
N/A e.g not company employee	2.8%

Table E.3: Time Employed at BAA Glasgow (Years)

Base	100.0%
Your Main Department / Function	
Airport Senior Management	22.2%
Airside Operations	2.8%
Business Support Services	8.3%
Customer Service	5.6%
Development	8.3%
Finance	-
Fire Service	5.6%
H&S	11.1%
Maintenance	19.4%
Property/Retail	11.1%
Security	5.6%

Table E.4: Auditors Department

Base	100.0%
Your Specific Area Assessed	
Airfield Operations Offices	-
Airfield Operations Tower	-
Airfield Workshop	2.8%
Arran Court	16.7%
Emergency Services Hanger	2.8%
Erskine Court	33.3%
Facilities Maintenance Offices	13.9%
Fire Station	5.6%
HR Offices	2.8%
Logistics Store	-
Motor Transport	2.8%
Rooftop Office Complex	16.7%
Whitehouse Offices	2.8%

Table E.5: Specific Area Assessed

Base	100.0%
Your Organisation Level at BAA Glasgow	
-Director	8.3%
-Manager	66.7%
-Team Leader	2.8%
-Operational Staff	13.9%
-Support Staff	8.3%
-External to BAA	-

Table E.6: BAA Glasgow Organisation Level

Base	100.0%
Have you received 5S Training?	
Yes at BAA Glasgow	50.0%
Yes but not at BAA Glasgow	13.9%
No but would like 5S training	5.6%
No but I'm aware of 5S principles	19.4%
No	11.1%

Table E.7: 5S Training Received

Base	100.0%
How long have you been using 5S?	
I have never used 5S	13.9%
6 months or less	41.7%
7-12 Months	19.4%
1-2 Years	13.9%
2-5 Years	8.3%
5 Years +	2.8%

Table E.8: Duration of 5S use

Base	100.0%
Please select your 5S Roles	
Trainer	2.0%
Practitioner	20.0%
Implementor	12.0%
Champion	16.0%
Auditor	-
External Assessor/Consultant	2.0%
I have responsibilities for an Area	26.0%
I have no 5S role	16.0%

Table E.9: 5S Role Type

Base	100.0%
What type of benefits have you achieved from using 5S, pl...	
Improved quality (e.g less defects, less variation)	22.6%
Lower costs (e.g.quantified reductions or benefits to the business)	7.5%
Improved delivery (e.g customer lead-times reduced)	11.3%
Cultural benefits (e.g. more motivated workforce)	20.8%
Environmental / Safety (less spills, emissions, leaks, accidents etc)	15.1%
None	22.6%

Table E.10: 5S Benefit Types

Base	100.0%
Do you consider a combined approach of 5S and Environment...	
Yes	72.2%
No	2.8%
Not considered this before	25.0%

Table E.11: Benefit of Combining 5S and Environmental Management

Base	100.0%
Please select an option	
Extremely	19.4%
Highly	33.3%
Sometimes	47.2%
Slightly	-
Never	-

Table E.12: Personal Concern over the Environment

Base	100.0%
Are you concerned about the impact of increasing environm...	
Yes	75.0%
No	11.1%
Not considered this before	13.9%

Table E.13: Concern over increasing Environmental Legislation

Appendix F: Additional Survey Data

Response No.	Environmental Problems from Deploying LSS
1	Conservation and saving of Electricity Saving of Fossil Fuel
2	Increased use of chemicals in cleaning processes.
3	Issues arise in pan-continental supply chains where decisions have to be taken around Air Freight vs. Sea Freight
4	Issues within SLA but outside control limits are deemed acceptable by some colleagues.
5	We will never sacrifice safety or environmental impact to improve efficiencies.
6	As in Question Q17, there are no problems when the "feel-good" hype is eliminated and the issues are factually considered.
7	People cannot accept change cause problems to justify their existance
8	Change management issues have arisen with regards to clean desk policy and 5S/C issues.
9	The Supply chain changes from implementing lean can result in environmental issues e.g sourcing from china because there product is cheaper and quicker to recieve but co2 increases as a result
10	speed to market
11	Due to the variation in hardness levels of water around the world coolant formulas had to modified in order for them to work in each plan.
12	Some processes, once they are improved lead to waste when some elements are not considered, e.g. the implementation of liquids ban at security, the improved efficiency led to higher generation of waste which in turn created another bottleneck that was originally overlooked.
13	Lean is understood by line managers at a fundamental level (in many cases not all). This leads to, objective satisfying, enforcement of lean techniques and philosophies that can be over subscribed and ultimately non-productive. Experienced stakeholders are fully aware that this initiative will disipate once the box is ticked i.e. the storm before the calm.
14	Toyota Way - means all members follow same common methodogly of prblem solving. Change is precived as good
15	Experience from previous jobs
16	It is arguable that the increased deliveries have increased road transportation from our suppliers but we could counter that we are now using more local suppliers resulting in a shorter supply chain.
17	resistance to change
18	Don't know of any.
19	Some improvements to productivity were unknowingly unsafe
20	Somtimes with the methodology of Just do it , Kaizen and Six Sigma problem. People are mostly using Six Sigma project every where rather than Lean and rapis events
21	at the begining people see it as additional work
22	hope it has been reduced...
23	Disruptions in lead times and turn around times
24	only opportunities for improvement not problems
25	Only when stakeholders responsible for environmental issues were not involved in the process
26	Paper work experiments waste
27	Lean leads to Out sourceing.
28	Used in our manufacturing but not familiar with the results
29	In our pre-Lean stage, process waste was stored till large quantities of waste (fabric, semi-finished garments, rejected garments, metal watses such as broken needles) and disposed very infrequently. One of the first changes made during Lean implementation was the need to dispose this waste frequently, to avoid build-up (the 5-why to reduce the waste is another story). This frequent disposing of waste lead to constant permissions from Govt authorities, and all the relted hassles. This lead many of the process owners wondering why they need to do this. The only long-term solution, of course, is to get to the root cause of why this

Table F.1: Respondents Negative Environmental Experiences of using LSS

Response No.	Other types of Green LSS approaches experienced by respondents
1	there's no need to call it anything other than Lean Six Sigma. Only the consultants will need to call it something different in order to sell services.
2	We have considered the impact of the company on the environment with fespect to ISO18001 however our impact is minimal and consultations with BSI have established we need not go for full ISO18001, my company therefore adopt the procipIes of REACH.
3	Lean and Clean, MEP/EPA sponsored program
4	part of coc
5	Green LSS sounds like politically-correct bullshit to me. Treat ALL criteria under the same "rules of evidence" and the TRUE values will surface.
6	The organization have environmental targets that's considered in our six sigma projects if applicable
7	I have heard of the use not the terms
8	New name??? Same tools
9	Eco manufacturing
10	Lean is without limits - so lean do mean also we`ve to save our earth (GREEN is a part of lean)
11	Environmental Waste War
12	I know there is a LEEDS ceertificcatioj for buildings but have never had the opportunity to be involved or work with it.
13	ECO Living - acting global, thinking local
14	There is a lot of "branding" going on by consultants right now.
15	We use tools like 5S to help change to green.
16	N/A
17	I know of a guy on Thailand who is doing Lean and Green - Jean Fancois Laugier. No other details though
18	Have not heard or public document for Green six sigma or lean.
19	Lean and Green
20	Green Six Sigma, I think read about it
21	have not heard of them, but am VERY INTERESTED!
22	One corporation has publicity about green lean. It's IBM: - can't remember the exact terminology.
23	Although none of the above, there is a high awareness that environmental impact is the eighth waste

Table F.2: "Other" types of Green LSS Approaches Experienced by Respondents

Response No.	Other Types of "Drivers" to go Green
1	internal compant policy is to focus on good corporate & community citizenship
2	The company wants to be environmentally responsible.
3	Our organization is large. I'm not hearing a lot about being Green, and the motivation behind what efforts we are taking is not communicated. Part of it is just being a good corporate citizen, part is saving $$.
4	Survey required me to fill in an answer, but there is nothing driving us to become "green".
5	Makes sense
6	We have introduced a Business Improvement project to our customer in which we continuously vouch for "green sourcing" to our customers. For Example, for a customer interested in buying electirc lamps on bulk, we are batting for CFLs.
7	Reducing our environmental impact is a metric being tracked by the CEO.
8	planning for awareness programs on AIR & WATER, because the biggest concern in Inida is WATER & AIR
9	There is a legacy on "green" in our product developemtn from original work in 1960's
10	As stated earlier, environmental concerns are not different from any other concerns. They are NOT "special." We use the 6-branch Fishbone diagram ALL the time (using the 6 M's). One of the M's is Mother Nature, or environmental concerns. They are evaluated with the other 5 M's and ranked in importance just like other issues.
11	Brand image
12	We are not
13	Corporate directive from highest levels. I question if benefits are worth costs.
14	There are only two reasons why my organisation will become greener: 1) To make a gain 2) Prevent a loss. This could be, for example, financial , environmental, risk prevention/reduction etc
15	employees
16	Ethics
17	Our children's future
18	Employees
19	Reputation & image
20	ethics
21	Politically correct
22	Corporate headquarters is very committed to environmental improvements and challenges the operating sites to achieve aggressive green goals.
23	I think the corporate headquarters wanted to respond to the recent "green" movement by starting a Sustainability division
24	Right thing to do
25	Mangement and employees.
26	Sometimes going 'Green' differentiates a company from its competitors.
27	PR
28	To be seen a a good corporate citizen
29	Environmental Committment is fundamental " Core Value"
30	(1)Our own companys standards are much tougher than the requirment from others
31	It's the right thing to do for the community.
32	Interest from employees
33	There is a profitable opportunity when promoting green products & services and expanding lean sigma to include green and sustainability initiatives within the organization. 3P's: profit, plante and people
34	Apply green to reduce costs
35	Customers requirement and ISO 140001 certification.
36	Main driver is cost savings. Reduced waste both material and energy. Also reduction of costs for handling / disposal of hazrdous materials
37	internal plan to excel.
38	Corporate initiatives
39	The company's own initiative to become environment-conscious / friendly
40	No but question 28 should include population control

Table F.3: Other "Drivers" to go Green

Response No.	Why do Environmental Employees not work together on Business Process Improvement Projects?
1	As of yet, the Lean/Sigma team appears to be siloed - their considerations of environmental stakeholders is not yet apparent. As an internal auditor I have found no evidence the Environmental Engineer is being routinely consulted during the project planning phase. I have taken it upon myself to teach the environmental engineer the principles and general terminology of lean, and how to evaluate the potential impacts on manufacturing by, for example the proposed relaxing of plant room temperature and humidity limits.
2	There are no lgislative requirements on the companies business that require us to link environmental considerations to production.
3	The predominant focus of Lean efforts is improving the bottom line. Environmental benefits are sometimes a side effect of the Lean initiatives, not the main focus.
4	In our plant, our EH&S manager is a Certified Kaizen leader. He is also a member of the staff and participates in tollgates for all events to ensure no negative impact to health and safety (which includes environtmental issues).
5	We have no "environmental employees". There is no "company concern" for the environment.
6	lack of communication, support from departmental managers and senior management
7	A silo'd organisation undertaking alot of change means that the thinking required to link the two has not happened.
8	There is no Environmental representative in our organization.
9	Our company is small. 150 employees. There is only one environmental employee. Our Safety Manager takes care of all environmental issues. Our environmental processes are so small that they have not required any improvements.
10	Team members are always selected with the view to achieving the team goals. The fact-based goals dictate team membership, not "special" concerns such as the contrived list in Question Q27.
11	EHS staff is not technical or personally motivated enough to participate.
12	Now that I understand which environment you are talking about EHS & LSS can/should work together but in my 17 years as a LSS consultant in over 200 different engagements around the globe they have never worked together
13	I have had no experience of this taking place, however, due to the size of the company this may take place elsewhere.
14	bring in profit 1st. others 2nd...
15	Environmental issues seen as a necessary evil
16	management does little or nothing to enable cross functional action
17	Different approach and management team
18	The cost savings issues were in focus.
19	Early days in other parts of the organisation and people haven't quite made the connection
20	To the best of my knowledge, there has never been any impulse to do this
21	I Have done in previous positions
22	Needs to become a leadership outcome target for this to happen
23	Benefits (if any) of enviromental approaches not "currently" factored into stakeholders requirements.
24	The leaders in our organization who lead green efforts show little interest in lean thinking/methods.
25	Not considered as common goals.
26	There's little to no effect to the environment in many of the projects going on to justify needing an member of the environmental department.
27	there is no environmental employees
28	Currently we do not have Environmental services available
29	The improvement in environmental concerns has been a pleaseant side effect of Lean
30	No interest hasn't been considered
31	Unless the specific project involved environmental issues, wouldn't have considered including environmental employees.
32	Disconnect in understanding by management
33	we have just strated thinking green lean not much exprerience ...customers are pushing us to do so ...still manging change ...I am positve
34	Our organization culture is still adapting lean culture and it is used to work in silos. :)
35	I'm sure no one has even explored the possiblity of linking the two concepts and estimating the synergies derived out of it.
36	No concrete interest
37	There are no corporate objectives specific to the environment so this is not a fuction that gets BI attention
38	We have still not undertaken projects related to environmental metrics, but intend to do in future based on the GRI3 framework.
39	Lean is not widely accepted in the organization. Mostly ad hoc, grass roots improvement events.
40	Only just starting the Lean Journey and not yet linked to environmental improvements.
41	Not considered yet!
42	Silo management style. The two departments do not work together.
43	Our company does not have environmental employees
44	Nobody makes the link
45	Awareness, training, operational focus
46	Not directly, only when there are projects in the Safety, Health and Environment Department.
47	there is no linkage between the groups
48	At present the teams are not working together since six sigma deployment is still in nascent stages, but in future they would.
49	lean sigma maturity
50	not considered the link
51	EHS Manager is not aware of the benefits of Lean / Six Sigma; EHS team is also not well-versed in Lean / Six Sigma
52	As previous, not been considered

Table F.4: Respondents opinion of why Employees do not work together on BPI Projects

Response No.	LSS Alternatives that could be developed into Environmental Versions
1	I consider the biggest benefit to the environment is the delivery of a more efficient (less wasteful) organisation. As such LSS is green and needs no additional elements. The 'market' can then decide if the organisation serves a need.
2	Identification of potential projects.
3	Not sure
4	There IS NO NEED for a separate Green LSS! It is a degradation of an honorable, proven process to suggest that LSS needs specialization. LSS is a full-scope process that has many tools and methods to handle ANY problem. By pushing for a separate "Green LSS" it gives the Green Industry a bad name among those of us who are professionals in LSS efforts.
5	No need for special treatment of environmental problems in the projects.
6	I work for a large and very environmentally conscious automotive & heavy equipment manufacturer. My location is a plant that is an automotive parts remanufacturer and is highly ranked for our environmental program within our corporation. My personal take on our environmental system is that it has little to do with Lean. We are a union shop with ISO9000 & ISO14000 systems, all of which tend to hold to the status quo and therefore inhibit improvement. Our ISO systems are maintained by ~10 people (quality & environmental) while our Lean implementation is run by less than one person (by hours available.) In this business culture, changes are small and usually forced, and true culture change (the Real heart of Lean) is very, very difficult. Lean (& Six Sigma to a lesser degree) can improve any process because they seek truth, but you only get points of improvement (which disappear) unless culture changes. Therefore specific tools (lean or SS) are futile, unless people beli eve in why they should follow them.
7	Process is process -- all the tools apply, in the right order, at the right time by the right people. In the hands of the wrong people, the tools can do great harm.
8	Let me just say that these tools have been around for years. Whether you call it Lean, Six Sigma, Green Lean Six Sigma it does not matter. It is very basic. You have a problem. you follow the DMAIC process and solve the problem using the tools necessary to get the job done. It does not matter what you call it. I personally do not think we need another faction that is "unique" for only it's issue. Six sigma works because it is dynamic. It does not work when people. managers, or companies pigeon hole it for only one thng.
9	Reward and recognition systems.
10	Value Engineering
11	We developed the green VSM
12	I think a better approach would be to actively involve environmental/ Safety managers in problem solving, than to create new tools. I have on several occations facilitated workshop where good solutions were found, both in terms of delivery, cast and HSE by inviting HSE to participate
13	This question is odd. The environmental impact of a process is simply one aspect, and as such it also can be improved. The tools you mention above can be used for ANY process and considering an infinite number of aspects. No need to "develop" anything except the mindset of team members to include environmental impacts.
14	Difficult to say. Need to further study.
15	Change Management, Pugh Matrix, coaching & Mentoring
16	PFMEA APQP (not only in automotive), PPAP ISO , SPC, Improvement Monitoring and reporting Visualization
17	Cost Benefit Analysis RACI Model
18	Environmental is a question of defining the appropriate CTQs - so all of the above as necessary.
19	Aspect Impact Evaluation as per ISO 14001EMS
20	PDCA and A3. Define the problem first then the tool selection can be done. I would not try to develop any of the tools into Green Lean Six Sigma until I had a defined problem to solve.
21	(1)Kaizen activities (2)Theory of Constrains (3)Product & process understanding
22	An Integrated Management System that includes quality, EHS and Energy.
23	We would like to use simpler tools so that more employees can be involved. Examples include 5S, kaizen, 7 wastes etc. We also do not see relevance of some techniques such as TPM or SMED since we are not in manufacturing sector.
24	Any and all tools are applicable. Which tools are used depend on the situation and the problem you're trying to solve
25	I think that all of the above tools can already be used to deal with environmental issues
26	Really, I could have selected almost any of the above. You don't need to develop special green versions of these tools, they are generic and applicable to a host of situations. You make them green by applying them to green issues. E.g. an 8D on stopping the production of defects that are scrapped is green.
27	Total Product Life-Cycle. Expand the concepts of waste reduction and Value stream mapping through the total life-cycle of the product; from raw materials to disposal / Recycle @ end of life
28	Hypothesis Testing / Confidence Intervals ANOVA Regression Analysis
29	the M in DMAIC seems key to this

Table F.5: Alternative Environmental Versions of LSS Tools