Investigating the Green Impact of Lean, Six Sigma, and Lean Six Sigma: A Systematic Literature Review

Purpose - The academic literature and research lines exploring the effect of quality improvement methods on environmental performance still remain in early stages. The purpose of this study is therefore to investigate, through a systematic review of the existing academic literature, the environmental (green) impact of using quality and operations improvement methods such as Lean, Six Sigma, and Lean Six Sigma. This includes the impact on energy saving and the usage of natural resources.

Design/methodology/approach - This study follows a systematic literature review approach through which it analyses research papers published in top 16 operations and quality management journals. No specific time frame was established, but a set of keywords were used to shortlist the articles. A sample of 70 articles was finally shortlisted and analysed to provide a discussion on environmental concerns related to Lean, Six Sigma, and Lean Six Sigma.

Findings - The comprehensive review of shortlisted articles indicates that both Lean and Six Sigma can be considered effective methods to support the conservation of resources, combat global warming and saving energy. Various scholars provide evidence of this and as such, organisations should not only consider these methods to manage quality and improve operational performance but also meet environmental regulations. A set of research questions that demands further investigation has also been proposed based on the findings of this research.

Research limitations - This study is limited to a sample of 70 articles collected from top 16 operations and quality management journals. The search of journals is also limited to a set of key words (‘Lean’, ‘Green’, ‘Six Sigma’, ‘environment’, ‘sustainable’ and ‘sustainability’) used to shortlist the sample size.

Practical implications - The study shows that organisations can consider the adoption of Lean, Six Sigma and Lean Six Sigma to meet environmental regulations, save costs and also meet quality management standards. This will contribute in helping organisations to formulate more effective and inclusive strategies which do not only consider the quality and operational dimensions but also the environmental dimension.

Originality/value - Literature exploring the environmental/green impact of quality management methods commonly used in industry is limited. There is also a lack of studies aiming to investigate the green impact of Lean and Six Sigma in top operations and quality management journals. The study focusing on investigating the green impact of Lean, Six Sigma and Lean Six Sigma methods altogether is also a research first of its kind.

1. Introduction

Lean and Six Sigma are quality management methods that have been gaining significant popularity since they were proposed. They are also frequently used in conjunction and referred to as Lean Six Sigma. Over the years, these methods have been adopted by many organisations around the globe and are increasingly used to improve their operations and quality. Lean is mainly focused on the reduction of waste (Drohomeretski et al., 2014) and identifying activities that do not add value to a particular product (Holweg, 2007). On the other hand, by focusing on the critical quality characteristics of products that are important for customers, Six Sigma identifies and eliminates mistakes, defects or failures that may affect processes (Garza-Reyes et al., 2014a). These objectives and characteristics can generate a discussion on the impact of these methods on the environment. However, before we begin to discuss the green impact of these methods, it is important to provide some general overview of their main concepts, principles and tools.

Lean, also referred to as "Lean Manufacturing" or "Lean Production" (Holweg, 2007), is widely being used by manufacturing organisations to improve their manufacturing process and production through the reduction of waste. Developed from the Toyota Production System (TPS), Lean Manufacturing is a management methodology that is concerned with identifying components adding value to the product and reducing unnecessary components (Holweg, 2007). This then leads to the reduction of wastage of the other unnecessary resources used for production. The main goal of Lean is to reduce waste (Drohomeretski et al., 2014), however it also has the objectives of improving quality and reducing costs (Wang, 2010). Customers' needs are of utmost importance as the Lean method is aimed at "enhancing customer value" (Albert, 2009). The Lean philosophy is based on tackling seven types of waste; excessive production, extra amount of inventory, waste of time due to slow processing, employee or equipment motion resulting in waste, over processing, lack of value to product in transportation, and waste due to defects (Wang, 2010). Following this, an 8th waste was identified by Womack and Jones (2010), which refers to the misalignment of the product and customer needs. This has been added to the list of wastes used by companies that adopt Lean. Over the years, several tools have been developed following Lean principles. These include the 5S system, Kanban, and Single Minute Exchange of Die (SMED), among others (Wang, 2010).

On the other hand, Six Sigma is a quality improvement framework that was developed by Motorola to enhance business procedures (Matthews, 2006). It is defined as a system for attaining, maintaining and maximising successful business (Pande et al., 2000). It has rapidly gained popularity as it is useful for saving costs and increasing efficiency (Walsh, 2000), and is now used by numerous firms to improve business processes (Garza-Reyes et al., 2010; Shand, 2001). For Six Sigma to be applied successfully, the needs of internal and external customers have to be understood (Weiner, 2004). Once this is done, the methodologies and tools of Six Sigma can be deployed. DMAIC (Define, Measure, Analyse, Improve, Control) and DMADV (Define, Measure, Analyse, Design and Verify), are two popular methodologies of Six Sigma (Breyfogle III, 2003). DMADV is also referred to as DFSS (Design for Six Sigma) (Thakore et al., 2014). Both methods consist of five phases. DMAIC is used to enhance processes already in place, whereas DMADV is used when customers are dissatisfied with existing business practices or when current processes are unable to meet established goals. Hence DMADV is used for the design/creation of new processes (Andersson et al., 2006). This goes to show that DMAIC is more of a corrective scheme while DMADV is a preventive scheme. Firms have to identify their respective issues with quality and apply the more suitable method accordingly. The phases of both methods are shown in Table 1. The application of these five stages of Six Sigma requires a thorough understanding of each individual stage and thus rigorous trainings of these methods have to be conducted for employees.

[Insert Table 1 here]

It is clear from the review of the literature that both Lean Manufacturing and Six Sigma are quality and operations improvement methods that share some form of relationship with TQM though they were derived from different origins (Arnheiter and Maleyeff, 2005). Their goals of managing quality are rather similar and therefore both methods are frequently used in conjunction. Lean Six Sigma was first introduced in 1997 by a company in India (Atmaca and Girenes, 2013). As indicated earlier, Lean Manufacturing is a model that aims to reduce waste and gives organisations an overview of process improvements (Drohomeretski et al., 2014) by using various tools like Kaizen, Kanban, cellular manufacturing, etc. It also incorporates the usage of a 5S system (sort, straighten, scrub, systemise and sustain) to help with the elimination of waste (Kocakulah and Upson, 2004). On the other hand, Six Sigma is a model that delivers these improvements to the firm through a reduction in defects and improved quality (Drohomeretski et al., 2014). Lean aims to reduce waste through reduction in defects. This draws a parallel between Lean itself and Six Sigma, where decreasing defects is key for the enhancement of operations. Their common goals and the wholesome programme offered through the reduction of defects and waste explains the usage of Lean and Six Sigma conjunctively by organisations. Lean and Six Sigma complement each other, and this makes them a popular method together to meet the quality needs of an organisation. A study conducted by Shah et al. (2008), surveying 2511 companies, showed that Lean Manufacturing and Six Sigma combined are able to produce positive results and hence they can be used as complementary schemes.

There are various ways of combining both methods to deploy a Lean Six Sigma programme. Pojasek (2003) provides one of the ways in which both Lean and Six Sigma can be combined and terms this as the systems approach. Another technique for applying Lean Six Sigma is the application and combination of the Plan-Do-Check-Act (PDCA) cycle with DMAIC (Burghall et al., 2014). PDCA involves planning the goals and objectives of the programme, implementing it, measuring its effectiveness through a study of the results, and concluding if the programme was successful enough to continue. This is similar to the DMAIC methodology and the unison of both gives an organisation the best of both worlds. Both methods are of a 'cyclical' nature, which means that they have to continuously be repeated until the goal of the programme is reached. An additional approach of Lean Six Sigma involves applying Lean and Six Sigma as separate methods (Salah et al., 2010). Some believe that applying both simultaneously may not yield success and therefore should be used separately. This is done by implementing Six Sigma first, in order to increase the efficiency of processes and thereafter using Lean to increase the efficiency of systems (Crawford, 2004). Snee (2005) discusses the opposite, this is the usefulness of implementing Lean first to sort processes and reduce waste before using the more complicated Six Sigma to tackle the steps involved in each process. However, Salah et al. (2010) still argue that Lean and Six Sigma should be used at the same time to obtain optimum results. The main question that arises from these combinations is which method should be used for maximum productivity and positive results? Should it be solely Lean, just Six Sigma or the merger of both, Lean Six Sigma? And if Lean Six Sigma, then how does one select the methodology to be used? The method that best fits the culture, industry and nature of the organisation has to be chosen. However, more research is required in this area to help organisations make an informed decision to select these tools.

Since these quality and operations improvement methods are widely practiced in manufacturing organisations it is important to understand their impact on the environment. This also becomes essential as governments around the globe are forcing new environmental regulations which manufacturing organisations need to comply with to survive and remain competitive in the global market. Lean principle objectives are clearly aligned with the saving of resources, which is why it is viewed as an environmentally friendly method. This has resulted in the emergence of a paradigm termed 'Green Lean' which combines principles of Lean with efforts to promote sustainability (Garza-Reyes, 2015a; Garza-Reyes, 2015b; Garza-Reyes et al., 2014b; Dües et al., 2013). From the discussion above, it is also clear that Six Sigma's main goal is to reduce defects. The reduction in defects would mean a significant saving of resources, which is essential in order to promote sustainability of rapidly depleting resources. The saving of resources, however, is not the goal of Six Sigma and therefore it can be considered a by-product of the implementation of this method. As such, it can be said that Six Sigma impacts the environment positively. Attempting a Lean Six Sigma programme is beneficial as it ensures that those issues that are neglected by applying the methods individually are addressed (Bhuiyan and Baghel, 2005). It helps organisations to reduce defects and achieve increased speed of delivery while keeping costs down (Salah et al., 2010). This in turn creates an organisation that focuses on customer needs and considers employees necessary for decision making and maintains flexibility at the same time (Martin, 2007). Lean solves problems of waste but does not address variation, lacking an approach that provides effective analysis (Zamri et al, 2013). Six Sigma complements this by providing a programme addressing both issues (Zamri et al, 2013). All these factors eventually can lead an organisation to gain a sustained competitive advantage as continuous improvement and progress is encouraged, showing how beneficial Lean Six Sigma can be.

This study therefore aims to investigate the extent of the environmental (green) implication of Lean, Six Sigma and Lean Six Sigma approaches so far discussed in top ranking operations and quality management literature. The rest of the paper is organised as follows: Section 2 elaborates the systematic literature review methodology followed in this study; Section 3 reports the findings from the shortlisted sample articles, Section 4 discusses the environmental (green) impact of Lean, Six Sigma and Lean Six Sigma. And finally, Section 5 concludes this study. This section also highlights the limitations of the study and proposes a set of research questions which demands further investigation.

2. Research Methodology

2.1 Article Selection Mechanism

This research is focused on analysing the existing literature in operations and quality management, in order to derive the green implications of the Lean, Six Sigma, and Lean Six Sigma approaches. Journals have published various articles on the different aspects of these methods. Information about their application, methodology, benefits and shortcomings is widely available. While much research has been conducted on this, barely any focus has been made on assessing the environmental impact of their application. Since Lean is focused on the reduction of waste, one would expect discussions on its green impact. Likewise, Six Sigma is focused on the reduction of defects and thus this result in the saving of resources and energy, which also leads to discussions on its impact on the environment. The relationship of Lean and Six Sigma with environmental sustainability is a gap in the literature which this research aims to fill.

A systematic literature review involves studying selected articles searched from different databases and sources (Burgess et al., 2006). A number of systematic review papers have been published in the operations and quality management domain focusing on various important topics (Gligor and Holcomb, 2012; Garza-Reyes, 2015a). According to Easterby-Smith et al. (2002), literature review is a necessary step in structuring a research field and advancing our understanding of any emerging research area. This helps to identify the conceptual content of the field (Meredith, 1993) and can contribute to theory development (Seuring and Müller, 2008). In the related research area there have been few literature review papers recently. For instance, Albliwi et al. (2014) selected articles ranging from 1995 to 2013, resulting in a timeframe of eighteen years for a Lean Six Sigma literature review. And more recently, Garza-Reyes (2015a) reviewed 59 articles on Lean and Green published between the periods 1997-2015. However, as indicated earlier, there is a lack of research investigating the environmental (green) impact of Lean, Six Sigma and Lean Six Sigma altogether. Since environmental concern has become paramount for organisations, it seems appropriate to address this research gap.

This research therefore follows a systematic literature review approach which is based on collecting and analysing a set of published journal articles. This study aims to follow a similar structure and methodology of selecting articles from specific journals as suggested in the works of Mayring (2003), Burgess et al. (2006) and Garza-Reyes (2015a). According to these studies, the process of analysis contains four steps: defining unit of analysis, classification context, material evaluation and collecting publications and delimiting the field, see Table 2. Studies have indicated that following this systematic process assures a structured and effective literature review. In order to select journals for this study, peer-reviewed journal articles well positioned in the Association of Business Schools (ABS) rankings were selected. Some additional non-ABS listed journals (e.g. Journal of Cleaner Production, International

Journal of Lean Six Sigma, etc.) were also included in this study as they were publishing articles primarily around the chosen topic area. Most journals chosen were highly ranked and are popular journals for publishing research in this field. A total of sixteen journals were selected for the search. These shortlisted journals are shown in Table 3. Shortlisting through the use of keywords is an effective method as argued by Burgess et al. (2006), hence it was adopted for this study. Due to the limited amount of articles and information available on the environmental impact of the chosen methods, no particular timeframe was set and all articles related to this research were used from the selected journals. The journals were searched for articles with keywords 'Lean', 'Green', 'Six Sigma', 'Environment', 'Sustainable' and 'Sustainability' anywhere in the abstract, title or in the main body of the article. The results are summarised below in Table 4. This table presents the number of articles found in the selected journals in relation to the keywords used for the search. For example, when searching using a combination of the keywords 'Lean' and 'Green', no articles were found in the Journal of Operations Management, whereas 34 were found in the Production and Operations Management journal.

[Insert Table 2 here]

[Insert Table 3 here]

[Insert Table 4 here]

A large number of articles on Lean and Six Sigma were found in the journals, but when the search was filtered with keywords on green/environment, these numbers were reduced significantly. For example, the Journal of Operations Management yielded 58 articles when just 'Lean' was used as a keyword. However, when a combination of keywords were applied (e.g., lean + green or lean + sustainable/sustainability) no article appeared in the searching results. The articles' abstracts were therefore scanned for relevance to environmental issues as many articles that were shortlisted did not bear any relation to the topic at hand; especially in the case of Six Sigma, where the keyword 'Green' could refer to the green belt certification. The keyword 'Environment' refers to the natural environment surrounding us as well as working environments with research and development. There were also some overlaps in the search, for example, the Production and Operations Management Journal yielded some of the same articles for 'Lean' with 'Green' and 'Lean' with 'Environment'. Likewise, the articles on Lean Six Sigma appeared under the searches of 'Lean' as well as those of 'Six Sigma'. Therefore, it was necessary to sift through the articles to only choose relevant papers for the sample. After a comprehensive search and consideration, a sample size of 70 articles was finalised for this study (see Table 5). For an accurate analysis, 10% of usable articles should be considered (Berenson and Levine, 1989). However, in the case of this study, the number of articles was limited and therefore all 70 articles were used to comprise the sample.

[Insert Table 5 here]

2.2 Article Categories

Wong et al. (2012) conducted a systematic literature review and categorised articles according to the methodology applied, journal of publication, subject discussed, and the year of publication. Likewise, this study followed a similar structure and first categorised articles according to the journal of publication to determine which journals published more information about the environmental issues as a result of these quality and operations management tools. This is shown in Figure 1.

[Insert Figure 1 here]

It is evident that the Journal of Cleaner Production contributes with most of the articles (16) published this area. This is perhaps due to the fact that most articles discuss environmental issues in this journal and as such hold much relevance towards this research study. The International Journal of Lean Six Sigma (11) also provides a significant amount of articles, while the rest of the journals contribute with a limited number of papers in this area.

The second method of categorisation was based on the number of articles found on Lean, Six Sigma and those that discuss the combination of both, i.e., Lean Six Sigma. This allowed us to deduce which method was most widely discussed in the academic literature (see Figure 2).

[Insert Figure 2]

It is evident from Figure 2 that Lean is more popular than Six Sigma when it comes to published studies on the environmental impact. This is possibly due to the fact that the main aim of Lean is to reduce waste (Drohomeretski et al., 2014) while Six Sigma aims to reduce defects (Dreachslin & Lee, 2007) and as such the Lean's philosophy is directly linked to the saving of resources and thus easier to discuss. This also shows the need for research to be conducted in the area of Six Sigma and Lean Six Sigma to investigate their impact on the environment and society.

Following the work of Wong et al. (2012), the third categorisation segregates the articles into theoretical and application studies, or those that deal with both. Some articles discuss methods and solely rely on theory to explain a phenomenon. These articles were put under the theoretical category. Some articles rely on case studies in organisations or applications of the methods. These were put under the application category. Those that combined theory and application were placed under the category of both (see Table 6).

[Insert Table 6]

The fourth and final form of categorisation was based on the year in which the articles were published. This was adapted from the works of Perkmann et al. (2013) and Garza-Reyes (2015a), where the articles chosen were plotted according to the year they were published in. This shows how recently the articles were published and if the research is indeed based on current information (see Figure 3). It is evident from the graph that the most number of articles were published in 2013 and 2014, providing a good indication of a research formulated on recent information. A relatively low number of articles were also published between 2000 and 2005 (See Figure 3).

[Insert Figure 3 here]

3. Findings

The aim of this study is to investigate the environmental (green) impact of Lean, Six Sigma and Lean Six Sigma methods. In order to investigate this, a sample of 70 articles was shortlisted after a rigorous search in top 16 journals. The list of articles used in this study is listed in Table 7. The distribution of the journals shows that most papers around green/environmental/sustainable aspects were published recently. This is a clear indication that environmental sustainability has recently become a prominent area for research.

[Insert Table 7 here]

Lean's objectives are clearly aligned with the saving of resources, for which it can be viewed as an environmentally friendly method. The 'Green Lean' method is a perfect balance of profitability and protection of the environment which organisations can adopt (Gordon, 2001). Organisations that implement Lean thinking and Green principles simultaneously are considered to perform better (Kitazawa and Sarkis, 2000). This supports research by Bergmiller and Mccright (2009), which shows that companies applying just Lean do not perform better than those applying Lean with Green. This is due to the overlapping themes of Lean and Green that include waste reduction, techniques for waste reduction, reducing lead times and greener supply chains (Dües et al., 2013). The Lean and Green implementation includes using Lean tools like the 5S system, Kaizen, Kanban and others, which leads to the Green paradigm (King and Lenox, 2001). However, it is also essential to note that the way Lean is largely dependent on the skills of the leaders executing the method and active employee participation, the objectives of Lean and Green will also be met if the leaders/managers have a mind-set of trying their best to be as environmentally friendly as possible and employee actively cooperate in these initiatives.

The review of literature also clearly highlights that Six Sigma's main goal is to reduce defects. Reduction of defects would mean a significant saving of resources, which in this case is essential to promote sustainability of rapidly depleting resources. The saving of resources, however, is not the goal of Six Sigma and therefore it can be considered a by-product of the implementation of a Six Sigma programme. As such, it can be said that Six Sigma impacts the environment positively. Despite the correlation between Six Sigma and the conservation of resources, there is not much information of the effect of Six Sigma on the environment. This can be seen from the small number of Six Sigma publications present in the sample of 70 articles. Only 14 articles discuss any link that Six Sigma may have on sustainability, whereas 53 are on Lean and its linkages with sustainability. Lee et al. (2014) discuss how Six Sigma can be used for the management and improvement of energy efficiency, which is another way in which Six Sigma can prove to be useful for green initiatives. The necessity of organisations to implement green programmes is due to pressure by the governments and non-government organisations that support clean practices (Lee et al., 2014). Six Sigma can be therefore considered as a useful method for organisations to adopt in order to improve their quality and operations while at the same time meet environmental rules and regulations.

It was evident from discussions that the Lean Six Sigma approach can also be beneficial since it overcomes the aspects often neglected by applying the methods individually (Bhuiyan and Baghel, 2005). The application of both methods helps organisations to reduce defects while simultaneously increasing the speed of delivery and reducing costs (Salah et al., 2010). As a result, Lean Six Sigma creates an organisation that focuses on customer needs and considers employees necessary for decision making while maintaining the flexibility at the same time (Martin, 2007). However, both methods have their own shortcomings; for example, Lean can reduce waste but does not address variation, whereas Six Sigma addresses variation. Therefore, the application of Lean Six Sigma can lead an organisation to gain a sustained competitive advantage as continuous improvement and progress is encouraged.

As discussed earlier that both Lean and Six Sigma have positive impacts on the environment, it is likely that their combination will naturally produce the same effect, if not better. The saving of resources is achieved through waste and defect reduction in Lean Six Sigma. Applying either method prior to the other or applying both methods simultaneously can yield the conservation of resources. Zamri et al. (2013) discuss a programme termed Green Lean Six Sigma (GLSS) that focuses on the enhancement of environmental performance while implementing Lean Six Sigma. GLSS is an emerging concept that can prove to be useful as it promotes social responsibility, which companies can tap on to fulfil environmental laws and regulations. Stefan and Paul (2008) show how applying such green concepts can improve a firm's financial performance. This is due to the fact that company's stakeholders are satisfied and increased access to specific markets can be reaped, promoting business and thereby improving financial performance. Studies also show that policies concerning the environment can stimulate innovation in organisations. This can eventually lead to lower costs as savings are made on payments and tariffs for polluting the environment (Zamri et al., 2013).

4. Discussion

4.1. Lean's Impact on Resources

Lean principles guide organisations to eliminate waste. Natural resources and raw materials are scarce and therefore Lean principles can result in the conservation of resources, if not directly, indirectly through the elimination of waste. Review of literature on Lean from the shortlisted samples show that a number of Lean tools are in use and researchers have highlighted how they can conserve resources. For example, Chiarini (2014) studied the impact of five Lean tools, i.e. Value Stream Mapping (VSM), 5S, cellular manufacturing, Total Productive Maintenance (TPM) and Single Minute Exchange of Die (SMED), on the environment. VSM identifies waste from production, helping organisations to save materials. SMED oddly enough, did not show any impact on the environment. The 5S system can help to identify leakages and spills thus preventing the wastage of resources (Wong and Wong, 2014; Chiarini, 2014). Wong and Wong (2014) developed a 'lean-ecosphere' system of managing operations for a manufacturing firm. This helped the company to organise the available resources and the time at hand, to ensure that the Lean philosophy works to reduce waste. Similarly, Aguado et al. (2013) developed a model that improves a Lean system of production using processes of environmental innovation. New models focused on Lean, such as those discussed here, can be useful for organisations to help them conserve resources.

VSM is one of the most frequently used tools in Lean implementation as it identifies issues within the processes that can be improved to create increased efficiency. An example of such is reported in the work of Matt (2014), where the VSM approach was used in a Lean engineer-to-order system of an Italian steel firm. Delayed submission of drawings and shipping lists, improper coordination of parts required for assembly, excessive stock and deliveries that turned out to be faulty were identified as process errors through VSM. The use of VSM in this case helped the organisation to save time, cost and resources once the problems were rectified. Lean tools can be used in specific areas of a firm's processes. For example, Azadegan et al. (2013) reported the use of Lean in reducing waste in the purchasing wing of a firm through management of suppliers and inventory. Reducing waste and recycling materials are both part of environmentally-friendly practices and the applicability of Lean can amplify this (Wiengarten et al., 2013).

De Souza and Carpinetti (2014) give an overview of the types of waste that Lean can work to combat. They used the Failure Mode and Effect Analysis (FMEA) approach in a manufacturing firm to identify and eradicate these wastes. Producing more than what is required, longer processing times, inefficient processes, product defects and the inability to use resources to its full potential were identified as factors that result in the wastage of resources. Lean's aim of solving these internal problems showcase its capability of being a method that promotes sustainability of resources. The FMEA approach can be said to be useful at tackling waste as Sawhney et al. (2010) also provide a programme of three stages which incorporates the usage of a modified FMEA approach in the third stage. The programme is based on four vital resources required to maintain the systems that are part of Lean: staff, machinery and equipment, resources for production and scheduling. The maintenance of these is crucial for the success of Lean as an environmentally friendly method.

One way in which Lean aims to reduce waste is through the reduction of defects. Faulty products have to be disposed of and thus some precious resources are discarded. A study carried out by Murugaiah et al. (2010) in a manufacturing firm depicts the usage of a 5-why analysis, which is another lean tool traditionally used for problem solving, to completely eradicate defects. They showcase the application of a Pareto chart to prioritise issues that needed to be addressed. The method applied resulted in a "zero scrap", which shows how the Lean philosophy can encourage green practices through the reduction of defects, Lean can also contribute to the creation of greener supply chains. Lean implementation can make supply chains more efficient by excluding waste that adds no value to the product (Found and Harrison, 2012). Reducing the usage of unnecessary resources, encouraging recycling of materials, sharing the environmental risks and cutting down on transport time, are part of the green supply chain practices that Lean utilises (Carvalho et al., 2011). The recycling of materials in the production process by implementing Lean is further supported in the work of Piercy and Rich (2015). Carvalho et al. (2011) show how these green supply chain practices are complemented by the Lean, Agile and Resilient paradigms, which display synergy and works as an environmentally friendly programme. Duarte and Machado (2013) also discuss this synergy of Lean and Green through reviewing various business models, showing how it reduces the negative impact on the environment by utilising resources to its full potential instead of wasting them. We see a prevalence of the link between Lean, Green, Agile and Resilient (LARG) paradigms in supply chain management as Cabral et al. (2012) also explore a model as such in the automotive industry. It is thus evident how the Green paradigm is taken up with Lean to maintain competitiveness, supporting the fact that Lean is a method that promotes environment sustainability.

Using Lean in supply chain management encourages sustainability measures to be put into practice and significantly improves environmental performance (Hajmohammad et al., 2013). Martinez-Jurado and Moyano-Fuentes (2014) point out that Lean is usually used by manufacturers and suppliers in the first tier instead of being used throughout the entire supply chain. If used throughout, it may prove to be even more effective than it is already known to be. Pagell and Shevchenko (2014), however, suggest that despite applying Lean in the supply chain of manufacturing firms (e.g. the automobile firms) it still produce products that utilise resources that are non-renewable. A contrast to the positive link between Lean and sustainable supply chain management is also pointed out by Pagell and Wu (2009). They studied ten companies and deduced that despite the vast amount of literature that suggests that Lean leads to sustainable supply chains, Lean may not be a factor that promotes sustainability. Their view is that only one of the ten companies that they studied applied Lean appropriately and hence achieved sustainable supply chains due to designing the reverse chain in a manner that did not disrupt processes of the forward chain. While their study points out the difficulty in applying Lean appropriately, it is premature to suggest that Lean is not a factor that contributes to sustainability. This would hence be a consideration for companies intending to conserve resources that maximum benefits should be extracted out of the Lean application.

The emerging combination of Lean and Green has become so well known that “Lean and Green” can be considered a new method on its own. Just like Lean, Green advocates the elimination of seven wastes: unnecessary usage of water, unnecessary power usage, exploitation of resources, pollution, litter, greenhouse effects and eutrophication (Verrier et al., 2014). A number of researchers such as Dües et al. (2013), Garza-Reyes et al. (2014b), Garza-Reyes (2015a) and Garza-Reyes (2015b) have advocated the integration of Lean and Green since both maintain synergies related to waste reduction, lead time reduction, product design and use of various approaches and techniques to manage people, organisations, and supply chain relations. Dhingra et al. (2014) discusses the Lean and Green combination by studying the available literature and state how Lean is aimed at conserving resources while Green also aims to do the same through recycling, reusing and remanufacturing. Lean and Green can be also integrated into other models like ISO 9001 and 14001 (Kurdve, 2014). ISO systems are said to be useful to identify processes that result in waste and as such can provide synergy for a Lean and Green programme by encouraging less depletion of resources. Lean and Green can also be used to improve supplier practices through influence of their buyers (Simpson and Power, 2005).

Governments around the globe have started regulating businesses that cause harm to the environment and impose certain rules and restrictions that organisations have to follow. As a result, many organisations have started to adopt Lean as a method to ensure they are in line with these regulations. Pullman et al. (2009) shows that the attractiveness of Lean is not only due to its positive impact on quality but also due to its impact on the environment and social practices that portray a responsible image of the firm.

4.2. Lean and Energy Conservation

In their study, De Souza and Carpinetti's (2014) identified events that led a manufacturing company to waste resources. These included unnecessary motion, transport and unused capacity of machinery during periods of lower production. Unnecessary motion, transport and unused capacity involve the usage of energy and technology for processes to be run, and as such they lead to wastage of energy. Lean is aimed at tackling these issues and can therefore play a vital role in the conservation of energy.

Lean incorporates the usage of one of the tools, Kaizen, which encourages continuous improvement throughout an organisation. Kaizen is a process improvement activity widely being practiced by organisations. It is thus considered to be vital for the application of Lean (Bateman, 2005). Bateman and David (2002) report the application of Kaizen in a power generation organisation and show the reduction of 25% in cycle times. This demonstrates how using Lean in power generation industries can aid the conservation of energy through the usage of process improvement activities. Pampanelli et al. (2014) support this case of Kaizen reducing energy consumption through their study of a production cell. Energy flow in the cell was reduced in the range of 5-10% showing how a Lean and Green model can aid the sustainability movement by decreasing energy consumption.

In addition to Kaizen, Lean includes the usage of the 5S system to create order in a work environment. This supports more efficient operations, which result in a lower amount of energy being used, accounting for environmental benefits (Wong and Wong, 2014). Usage of another Lean tool, Cellular Manufacturing, also leads to a decrease in energy consumption (Chiarini, 2014). Ball (2015) also report that Lean complements reduced energy usage. Chan and Kumar (2009) applied Leagile principles, which is a combination of Lean and Agile principles, in a manufacturing firm and reduced the wastage of time in its production process. This indirectly contributed to the conservation of energy and hence the application of Leagile principles can also be explored in this context of environmental (green) impacts.

Based on the discussions presented above it is evident that Lean and Green complement each other. One of the wastes that Green addresses is the unnecessary power usage (Verrier et al., 2014). We see this evidence also in the work of Besseris and Kremmydas (2014). Applying Lean's philosophy of eradicating waste and Green's aim of reducing energy consumption can thus help promote environmental sustainability.

4.3. Global Warming, Pollution and Lean's impact

One may wonder how a quality and operations improvement philosophy like Lean can contribute to decrease in pollution and thereby combat global warming. In this line, Piercy and Rich (2015) consolidate the findings of researchers that show a reduction in emissions from transport and production operations through Lean and the achievement of more efficient processes. Being a greenhouse gas, carbon dioxide contributes to the change in climate and is of global concern. One of the solutions to global warming and pollution is to reduce the emission of carbon dioxide into the atmosphere. Lean production, through reduction of waste, can help to prevent pollution as it results in shorter cycle times and higher utilisation of resources (Golicic and Smith, 2013). King and Lenox (2001) also support this notion as they found evidence of Lean resulting in reduced pollution. The development of a Carbon-Value Efficiency metric from Lean and Green methodologies proposed by Ng et al. (2015) helped to decrease the carbon footprint during the production of metal stamped parts. This displays another way that Lean can help to reduce pollution and global warming.

Manufacturing processes and production is such that both greenhouse gases and toxic gases are released into the atmosphere in large amounts. Measures have to be taken to control emissions and thus organisations should engage in projects that prevent the excessive emission of pollutants. Galeazzo et al. (2014) provides evidence from three such projects used in two organisations to show how through the usage of Lean and Green principles pollution can be prevented. They also propose that implementing both paradigms at the same time can result in a better performance of operations than applying them one after the other, as the latter solves issues from just one perspective and poses constraints on possible practices.

4.4. Six Sigma's Impact on Resources

Six Sigma's purpose of reducing errors and defects in processes tends to discourage the depletion of resources, as more accuracy means that fewer resources will be wasted. Many organisations have implemented Six Sigma in order to control resource consumption; another reason for this is to reduce cost by only utilising resources that are necessary. A study of the Amway Taiwan Company by Wei et al. (2010) shows useful support to Six Sigma as a programme that helps to save resources. Customer needs were analysed and used to tweak production in order to improve the replenishment process (Wei et al., 2010). This, in turn, reduced the waste of products that were not aligned with customer requirements.

It is assumed that a highly technical quality management programme like Six Sigma would be very costly and therefore can mostly be used by large enterprises where budgeting is not a significant problem. However, the application of Six Sigma reported by Kaushik et al. (2012)

in a small enterprise that manufactured bicycle chains shows that the opportunity of conserving resources with the support of Six Sigma can also be reaped by smaller firms. In this company, an increase in the sigma level was observed from 1.40 to 5.46 through improvement in the accuracy of cycle chain bush (Kaushik et al., 2012). The decreased rejection of products helps to reduce cost and save resources, making Six Sigma also attractive to smaller and medium sized firms. Gijo and Sarkar (2013) have similarly applied Six Sigma for developing wind farm roads in India. It resulted in the improvement of the quality of such roads and as such, constant repair work for damaged work was avoided, allowing costs to be reduced and resources to be conserved. The casting industry has also been explored by Kumar et al. (2013), where Six Sigma reduced defects due to improved processes, decreasing wastage of valuable materials. More recently, Gijo et al. (2014) explored a foundry industry's application of Six Sigma, finding significant reduction of rejections and cost savings of US$8000 per annum. Through these studies, it is evident that Six Sigma has been successfully used for the reduction of resource consumption.

4.5. Impact on Energy Management by the implementation of Six Sigma

As discussed in this study earlier, the implementation of Six Sigma reduces defects. This in turn can have a significant impact on the energy used in manufacturing processes. Using the DMAIC methodology, Lee et al. (2014) show how Six Sigma can be used to save energy, making the case for Six Sigma as an environmentally friendly programme. The study showed various opportunities to save energy, which included investing in insulation, repairing damaged equipment, reducing the usage of lighting and using energy-saving lighting (Lee et al., 2014). Another example of Six Sigma and energy management is discussed by Eberly (2006), who showed the reduction of energy usage through a Green belt project and a trailblazing method. Encouraging such energy saving measures can also help lower costs which organisations may find desirable. As evident from these studies, Six Sigma can be seen as a means of managing energy usage and firms can choose to implement it as part of their greener initiatives.

4.6. Lean Six Sigma's Impact of Resources

Lean Six Sigma is gaining a lot of popularity. This is evident from a number of publications on this topic (Cabrita et al. 2015; Panat et al., 2014; Snee, 2010). Snee (2010) shows how Lean Six Sigma can be used to support finances during economic downturns. It is also used to eradicate waste and bring about improvements in processes (Panat et al., 2014). Observation, a Lean tool, can be used in a Lean Six Sigma programme to enhance the speed of processes (Arumugam et al., 2012). Intel's reduction of idle time through the application of Lean Six Sigma (Panat et al., 2014) shows how both resources and energy can be conserved. As such, Lean Six Sigma can also be considered a methodology that helps achieve a sustainable environment. Its constituent methodologies provide the same results.

Lean and Six Sigma have principles focused on solving problems of quality and operations management as soon as they are identified (Roth et al., 2008). Roth and Franchetti (2010) show how Lean Six Sigma was used by a printing firm to solve issues like low productivity and identifying activities that do not add value. This allows the firm to decrease energy consumption caused by delays in machinery, supporting the idea that Lean Six Sigma could also be an energy-saving method. Implementing Lean Six Sigma, however, also comes with its own complications. Long term success of the programme can be achieved if senior and middle management work together to formulate strategies and solutions (Manville et al., 2012). These studies show that although Lean Six Sigma has the potential to conserve resources, more research is needed to support this assertion.

5. Conclusions, Limitations and Future Research Directions

The effect of Lean and Six Sigma on the environment has been examined in detail in this study. The effect of the combination of these methods, i.e., Lean Six Sigma was also discussed. The methodology of this literature review was developed through a systematic search of sixteen journals to yield 70 articles using specific keywords. Categorisation of the articles was also conducted for easy analysis and to provide a depiction of what the literature has addressed about Lean and Six Sigma and their green impact. An overview of both methods was then provided, which formed the foundation for this study linking theory and literature together. Using the articles that were shortlisted, the effectiveness of Lean, Six Sigma and Lean Six Sigma as environmentally-friendly methods was discussed. Research aimed to investigate and link the positive impact of these methods on the issues of energy management, global warming, pollution and usage of resources. The study shows that organisations can engage in these quality and operations improvement methods to support their compliance with environmental regulations and save costs while also meeting quality management and operations standards.

Various articles analysed in this study included information on the issues surrounding the impact of these quality and operations management methods on the environment; however, some did not bring forward the issue of sustainability. As such, inferences were made from those that did not provide direct links to the impact on the environment. These inferences provide a new and fresh perspective to this issue, which can fuel further research. In conclusion, it is evident through the comprehensive analysis of sample articles that both Lean and Six Sigma are indeed useful in supporting the conservation of resources, combating global warming and saving energy. Various scholars provide evidence of this and as such, organisations should actively consider these methods to manage quality and meet environmental regulations.

As in all studies, this research also faced some limitations. The study is limited to only 16 journals and 70 articles sourced from these journals using a limited number of specific keywords. Including more journals and articles by broadening the scope could have provided a more holistic view of the matter at hand. Also, the limited amount of information on the link between both methods and the environment in the articles reduced the sample size to be studied.

The analysis conducted provides many directions for future research. It is evident from this study that there is a lack of research and therefore scarcity of articles exploring Six Sigma's impact on the environment. The positive or negative consequences on the environment as a result of the Six Sigma implementation have yet to be explored in all industries. Conducting more research in this area can give organisations an insight into the application of Six Sigma. While Lean has a significant amount of articles and information on its environmental considerations, more can be explored in this aspect as well. These gaps can be filled by examining individual organisation's style and programmes of applying the practices of Lean, Six Sigma and Lean Six Sigma. Thereafter, a common ground can be found between them to build a relationship between theory, methodology and practice. Finally, the conceptual and practical implications of other quality schools of thought, such as that of the 'loss to society' proposed by Taguchi (Ross, 1988), may also be investigated from an environmental perspective. Specifically, the investigation of their synergies and divergences will contribute to the advancement of this area.

Some specific research questions that can be explored in the future include:

- What aspects of Six Sigma make it suitable as a measure for sustainability?
- What are the environmental incentives for the various organisations aiming to implement Six Sigma?
- Does the implementation of Lean Six Sigma assist organisations to be more environmentally sustainable?
- How environmental sustainability pressures affect the choice of quality improvement programmes?
- What are the challenges of Lean and Green implementation?
- Does the inclusion of the Green dimension calls for a new theoretical foundation for quality improvement?

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Figures

Figure 1: Categorisation of number of articles in journal publications

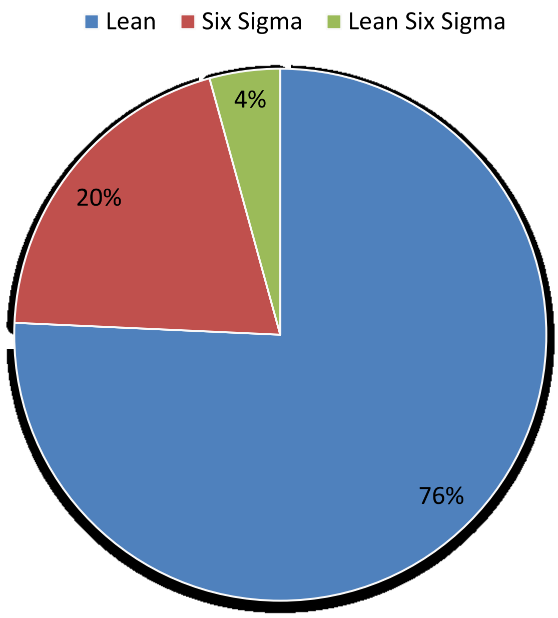

Figure 2: Categorisation of articles for each method

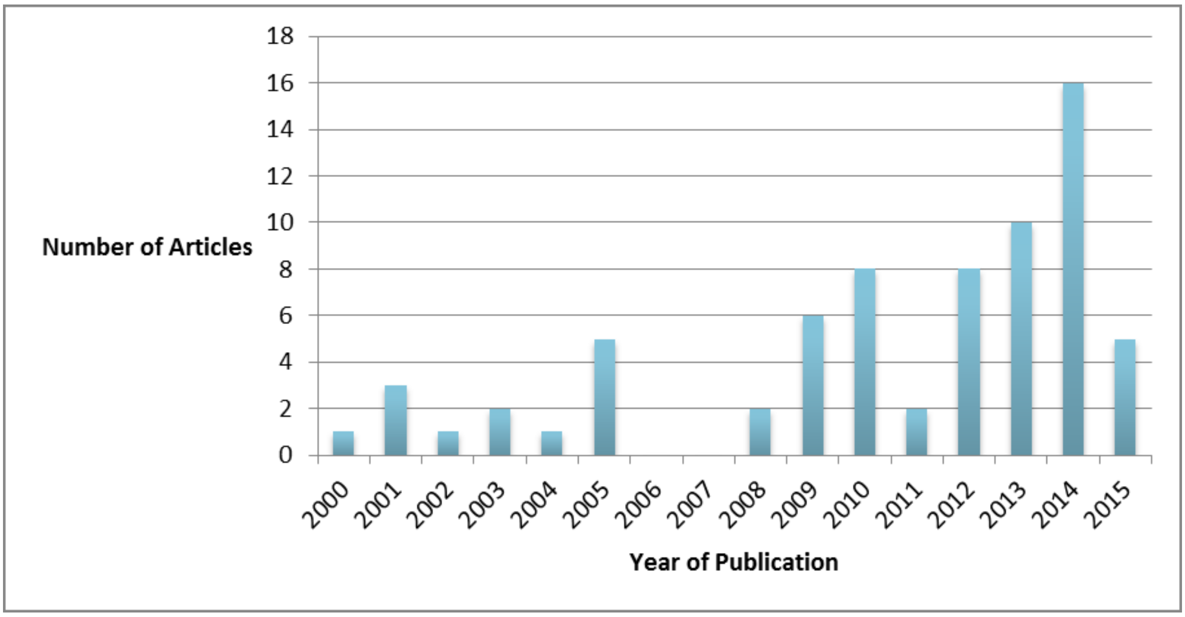

Figure 3: Categorisation of articles according to year of publication

Tables

Table 1: DMAIC vs DMADV (Adapted from Thakore et al., 2014)	
DMAIC	**DMADV**
D: Define process that requires development	D: Define objectives that satisfy customer needs
M: Measure critical factors that affect processes	M: Measure factors that affect quality
A: Analyse factors to improve	A: Analyse to devise alternatives
I: Improve by creating and implementing a solution	D: Design an alternative method
C: Control by ensuring successful and sustainable improvement	V: Verify method before it is put in place

Table 2: Summary of Research Methodology

Unit of Analysis	The sources include high ranked peer-reviewed papers in the operations and quality management area and more noticeably publishing papers on Lean manufacturing, Six Sigma, Lean Six Sigma, and environmental/green aspects
Type of Analysis	Qualitative
Period of Analysis	Not specific due to the limited amount of papers that have been published combining, Lean, Six Sigma, Lean Six Sigma and green/environmental impact
Search Source	Journals listed in the ABS 2015 list plus few additional relevant journals
Keywords used	Authors have used following terms and their combination to shortlist the articles for evaluation in this study. Lean; Six Sigma; Lean Six Sigma; environment; sustainability; sustainable
Journals selected for this study	• Journal of Operations Management • Production and Operations Management • International Journal of Operations and Production Management • International Journal of Production Economics • International Journal of Production Research • Total Quality Management & Business Excellence • Managing Service Quality • International Journal of Lean Six Sigma • The TQM Magazine • International Journal of Quality and Reliability Management • International Journal of Health Care Quality Assurance • Supply Chain Management: An International Journal • Journal of Manufacturing Technology Management • Journal of Supply Chain Management • Journal of Cleaner Production • Strategic Planning for Energy and the Environment
Total number of articles used in this study	70 articles were selected after the search and consideration

Table 3: Shortlisted Operations and Quality Management Journals

1	Journal of Operations Management
2	Production and Operations Management
3	International Journal of Operations and Production Management
4	International Journal of Production Economics
5	International Journal of Production Research
6	Total Quality Management & Business Excellence
7	Managing Service Quality
8	International Journal of Lean Six Sigma
9	The TQM Magazine
10	International Journal of Quality and Reliability Management
11	International Journal of Health Care Quality Assurance
12	Supply Chain Management: An International Journal
13	Journal of Manufacturing Technology Management
14	Journal of Supply Chain Management

15	Journal of Cleaner Production
16	Strategic Planning for Energy and the Environment

Table 4: Number of Articles Found in Initial Search

Journals \ Keywords	'Lean', 'Green'	'Six Sigma', 'Green'	'Lean', 'Environment'	'Six Sigma', 'Environment'	'Lean', 'Sustainability'	'Six Sigma', 'Sustainability'	'Lean, 'Sustainable'	'Six Sigma', 'Sustainable'
Journal of Operations Management	0	0	5	0	0	0	0	1
Production and Operations Management	34	13	101	33	21	5	33	10
International Journal of Operations and Production Management	1	0	18	0	11	1	11	1
International Journal of Production Economics	0	0	7	0	2	0	0	0
International Journal of Production Research	1	0	19	1	3	1	3	2
Total Quality Management & Business Excellence	6	27	24	47	11	21	18	33
Managing Service Quality	3	4	39	11	7	4	18	12
International Journal of Lean Six Sigma	3	2	9	12	5	7	7	11

The TQM Magazine	0	4	6	10	4	7	5	6
International Journal of Quality and Reliability Management	0	0	6	6	3	5	4	4
International Journal of Health Care Quality Assurance	1	0	0	4	3	1	4	1
Supply Chain Management: An International Journal	1	0	8	0	2	1	2	0
Journal of Manufacturing Technology Management	2	0	0	2	10	0	10	0
Journal of Supply Chain Management	31	6	84	16	29	6	44	8
Journal of Cleaner Production	18	0	7	0	16	0	14	0
Strategic Planning for Energy and the Environment	0	2	2	2	0	2	0	2

Table 5: Shortlisted Final Sample of Articles

Keywords / Journals	‘Lean’, ‘Green’	‘Six Sigma’, ‘Green’	‘Lean’, ‘Environment’	‘Six Sigma’, ‘Environment’	‘Lean’, ‘Sustainability’/ ‘Sustainable’	‘Six Sigma’, ‘Sustainability’/ ‘Sustainable’
Journal of Operations Management	0	0	1	0	0	0

Production and Operations Management	4	0	0	0	0	0
International Journal of Operations and Production Management	1	0	0	0	2	0
International Journal of Production Economics	0	0	2	0	0	0
International Journal of Production Research	1	0	2	1	0	0
Total Quality Management & Business Excellence	0	1	0	0	1	0
Managing Service Quality	0	0	1	0	0	0
International Journal of Lean Six Sigma	3	0	1	2	3	2
The TQM Magazine	0	1	3	2	0	1
International Journal of Quality and Reliability Management	0	0	2	0	2	0
International Journal of Health Care Quality Assurance	1	0	0	0	0	0
Supply Chain Management: An International Journal	1	0	1	0	1	1
Journal of Manufacturing Technology Management	2	0	0	1	0	0
Journal of Supply Chain Management	4	1	0	0	0	0
Journal of Cleaner Production	14	0	1	0	1	0
Strategic Planning for Energy and the Environment	0	2	0	0	0	0

Table 6: Categorisation of sample articles in journals

	Journal Name	Theory	Application	Both
1	Journal of Operations Management		1	
2	Production and Operations Management		2	2
3	International Journal of Operations and Production Management		3	
4	International Journal of Production Economics		1	1

5	International Journal of Production Research	2		2
6	Total Quality Management & Business Excellence	1	1	
7	Managing Service Quality		1	
8	International Journal of Lean Six Sigma	2	7	2
9	The TQM Magazine		7	
10	International Journal of Quality and Reliability Management		3	1
11	International Journal of Health Care Quality Assurance		1	
12	Supply Chain Management: An International Journal	1	3	
13	Journal of Manufacturing Technology Management		3	
14	Journal of Supply Chain Management		4	1
15	Journal of Cleaner Production	3	7	6
16	Strategic Planning for Energy and the Environment	1	1	

Table 7: Titles and Journal names of Short-listed articles

No.	Article Title	Name of Journal
1.	Application of Six Sigma methodology in a small-scale foundry industry	International Journal of Lean Six Sigma
2.	Applying the DOE toolkit on a Lean-and-Green Six Sigma Maritime-Operation Improvement Project	International Journal of Lean Six Sigma
3.	Improving marketing process using Six Sigma techniques (case of Saman Bank)	International Journal of Lean Six Sigma
4.	Innovation in management system by Six Sigma: an empirical study of world-class companies (International Journal of Lean Six Sigma)	International Journal of Lean Six Sigma
5.	Lean manufacturing implementation using value stream mapping as a tool: A case study from auto components industry	International Journal of Lean Six Sigma
6.	Lean Six Sigma – getting better all the time	International Journal of Lean Six Sigma

7.	Lean, agile, resilient and green: divergencies and synergies	International Journal of Lean Six Sigma
8.	Modelling lean and green: a review from business models	International Journal of Lean Six Sigma
9.	Process improvement for printing operations through the DMAIC Lean Six Sigma approach: A case study from Northwest Ohio, USA	International Journal of Lean Six Sigma
10.	The application of Lean Six Sigma to the configuration control in Intel's manufacturing R&D environment	International Journal of Lean Six Sigma
11.	Understanding the lean voice of the customer	International Journal of Lean Six Sigma
12.	Lean practices for quality results: a case illustration	International Journal of Health Care Quality Assurance
13.	Process improvement programmes: a model for assessing sustainability	International Journal of Operations & Production Management
14.	The relationship between lean operations and sustainable operations	International Journal of Operations & Production Management
15.	Sustainability: the elusive element of process improvement	International Journal of Operations & Production Management
16.	Agility and mixed-model furniture production	International Journal of Production Economics
17.	Constraint batch sizing in a lean environment	International Journal of Production Economics
18.	A decision-making model for Lean, Agile, Resilient and Green supply chain management	International Journal of Production Research
19.	Disentangling causal relationships of a manufacturing process using genetic algorithms and six-sigma techniques	International Journal of Production Research
20.	Performance optimization of a leagility inspired supply chain model: a CFGTSA algorithm based approach	International Journal of Production Research
21.	A time-based quantitative approach for selecting lean strategies for manufacturing organisations	International Journal of Production Research
22.	Critical success factors for Lean Six Sigma programmes: a view from middle	International Journal of Quality & Reliability Management

	management (International Journal of Quality & Reliability Management)	
23.	A FMEA-based approach to prioritize waste reduction in lean implementation (International Journal of Quality & Reliability Management)	International Journal of Quality & Reliability Management
24.	A modified FMEA approach to enhance reliability of lean systems (International Journal of Quality & Reliability Management)	International Journal of Quality & Reliability Management
25.	Scrap loss reduction using the 5-whys analysis (International Journal of Quality & Reliability Management)	International Journal of Quality & Reliability Management
26.	Combining organizational performance with sustainable development issues: the Lean and Green project benchmarking repository	Journal of Cleaner Production
27.	Concurrent multi-response optimization of austenitic stainless steel surface roughness driven by embedded lean and green indicators	Journal of Cleaner Production
28.	Does lean mean green?	Journal of Cleaner Production
29.	Green as the new Lean: how to use Lean practices as a catalyst to greening your supply chain	Journal of Cleaner Production
30.	Synergizing an ecosphere of Lean for sustainable operations	Journal of Cleaner Production
31.	Integrating and implementing Lean and Green practices based on proposition of Carbon-Value Efficiency metric	Journal of Cleaner Production
32.	Lean and green - a systematic review of the state of the art literature	Journal of Cleaner Production
33.	Lean and green in action: interdependencies and performance of pollution prevention projects	Journal of Cleaner Production
34.	Lean and green integration into production system models- experiences from Swedish industry	Journal of Cleaner Production
35.	A Lean & Green Model for a production cell	Journal of Cleaner Production

36.	Lean and green product development: two sides of the same coin?	Journal of Cleaner Production
37.	Lean management and supply management: their role in green practices and performance	Journal of Cleaner Production
38.	Lean Management, Supply Chain Management and Sustainability: A Literature Review	Journal of Cleaner Production
39.	Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers	Journal of Cleaner Production
40.	Model of efficient and sustainable improvements in a lean production system through processes of environmental innovation	Journal of Cleaner Production
41.	Environmental management and operational performance in automotive companies in Brazil: the role of human resource management and lean manufacturing	Journal of Cleaner Production
42.	Adaptation of the value stream mapping approach to the design of lean engineer-to order production systems: A case study	Journal of Manufacturing Technology Management
43.	Low energy production impact on lean flow	Journal of Manufacturing Technology Management
44.	Reducing the delivery lead time in a food distribution SME through the implementation of six sigma methodology	Journal of Manufacturing Technology Management
45.	The effect of environmental complexity and environmental dynamism on lean practices	Journal of Operations Management
46.	A Meta-Analysis of Environmentally Sustainable Supply Chain Management Practices and Firm Performance	Journal of Supply Chain Management
47.	Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars	Journal of Supply Chain Management
48.	Food for thought: Social versus Environmental Sustainability Practices and	Journal of Supply Chain Management

	Performance Outcomes	
49.	Unraveling the Food Supply Chain: Strategic Insights from China and the 2007 recalls	Journal of Supply Chain Management
50.	Why Research in Sustainable Supply Chain Management should have no future	Journal of Supply Chain Management
51.	Developing, implementing and transferring lean quality initiatives from the aerospace industry to all Industries	Managing Service Quality
52.	Lean and Green? An empirical examination of the relationship between Lean Production and Environmental Performance	Production and Operations Management
53.	Sustainable Operations Management	Production and Operations Management
54.	Environmental Performance as a driver of Superior Quality	Production and Operations Management
55.	Lean, Green and the quest for superior Environmental Performance	Production and Operations Management
56.	Building Energy Cost Savings From Six-Sigma Process Improvement Methods	Strategic Planning for Energy and Environment
57.	Six-Sigma Approach to Energy Management Planning	Strategic Planning for Energy and Environment
58.	Exploring synergetic effects between investments in environmental and quality/lean practices in supply chains	Supply Chain Management: An International Journal
59.	Supplier integration strategy for lean manufacturing adoption in electronic-enabled supply chains	Supply Chain Management: An International Journal
60.	Use the supply relationship to develop lean and green suppliers	Supply Chain Management: An International Journal
61.	Using Six Sigma to improve replenishment process in a direct selling company	Supply Chain Management: An International Journal
62.	A business process change framework for examining the implementation of six sigma: a case study of Dow Chemicals	The TQM Magazine
63.	A case study : Application of Six Sigma methodology in a small and medium-sized	The TQM Magazine

	manufacturing enterprise	
64.	Application of Six Sigma to improve the quality of the road for wind turbine installation	The TQM Magazine
65.	Improvement of Sigma level of a foundry: a case study	The TQM Magazine
66.	Integrated lean TQM model for global sustainability and competitiveness	The TQM Magazine
67.	Matching “environmental performance” and “quality performance”: A new competitive business strategy through global efficiency improvement	The TQM Magazine
68.	Observation: a Lean tool for improving the effectiveness of Lean Six Sigma	The TQM Magazine
69.	Lean Service: A literature analysis and classification	Total Quality Management and Business Excellence
70.	Six sigma basics	Total Quality Management and Business Excellence