# Exploring the role of lean thinking in sustainable business practice


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# Exploring the role of lean thinking in sustainable business practice

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**Abstract**

A large and growing body of literature has explored corporate environmental sustainability initiatives and their impacts locally, regionally and internationally. While the initiatives provide examples of environmental stewardship and cleaner production, a large proportion of the organisations considered in this literature have 'sustainable practice', 'environmental stewardship' or similar goals as add-ons to their core business strategy. Furthermore, there is limited evidence of organizations embracing and internalising sustainability principles throughout their activities, products or services. Many challenges and barriers impede outcomes as whole system design or holistic approach to address environmental issues, with some evidence to suggest that targeted initiatives could be useful in making progress. 'Lean management' and other lean thinking strategies are often put forward as part of such targeted approaches. Within this context, the authors have drawn on current literature to undertake a review of lean thinking practices and how these influence sustainable business practice, considering the balance of environmental and economic aspects of triple bottom line in sustainability. The review methodology comprised firstly identifying theoretical constructs to be studied, developing criteria for categorising the literature, evaluating the findings within each category and considering the implications of the findings for areas for future research.

The evaluation revealed two main areas of consideration: a) lean manufacturing tools and environmental performance; and b) integrated lean and green models and approaches. However the review highlighted the *ad hoc* use of lean thinking within corporate sustainability initiatives, and established a knowledge gap in the form of a system for being able to consider different categories of environmental impacts in different industries and choose best lean tools or models for a particular problem in a way to ensure holistic exploration. The findings included a specific typology of lean tools for different environmental impacts, drawing from multiple case studies.

Within this research context, this paper presents the findings of the review; namely the emerging consensus on the relationships between lean thinking and sustainable business practice. The paper begins with an overview of the current literature regarding lean thinking and its documented role in sustainable business practice. The paper then includes an analysis of lean and green paradigms in different industries; and describes the typology of lean tools used to reduce specific environmental impacts and, integrated lean and green models and approaches. The paper intends to encourage industrial practitioners to consider the merits and potential risks with using specific lean tools to reduce context-specific environmental impacts. It also aims to highlight the potential for further investigation with regard to comparing different industries and conceptualising a generalizable system for ensuring lean thinking initiatives build towards sustainable business practice.

## 1. Introduction

The world is facing unprecedented global environmental challenges such as climate change, population increase, biodiversity degradation and natural resource depletion. Sustainable development is viewed as an organizing principle for tackling these challenges (Macagno, 2013; Smith, Hargroves, & Desha, 2010). There is increasing attention on ways for manufacturers to become more sustainable, by minimising resource consumption while staying within carrying capacity of the earth (Jovane et al., 2008; Von Weizsacker, Hargroves, Smith, Desha, & Stasinopoulos, 2009).

Moser (2001) provides a succinct summary of sustainable business practice as "*business behaviour that leads to a net overall increase in the different forms of capital associated with sustainable development*". As identified by Serageldin (1996) more than 20 years ago, the types of capital to be considered in relation to sustainable development comprise productive capital, human capital, social capital and natural capital. On reflection, over the last two decades, although not all industries have completely embraced the culture of becoming eco-friendly or green, there is an emerging trend in considering environmental impacts when making business decisions (Schaper, 2002).

Organizations adopt tools such as environmental management systems, policies, audits, life cycle assessment, environmental accounting, sustainability reporting (Welford, 1996) and lean manufacturing are used in corporate environmental management to improve environmental performance in organizations (Quaddus & Siddique, 2011). A large and growing body of literature has investigated environmental sustainability initiatives and projects that companies have embarked on. However it is often concluded that that these are add-ons to core business with limited evidence of companies embracing sustainable business practice with regard to environmental sustainability.

Lean manufacturing is one of the strategies proposed in the late 1980s, focused on reducing waste (Ōno, 1988). Lean manufacturing systems are underpinned by resource efficiency, as they intend to deliver the same output while utilising fewer inputs, by means of minimising waste and finally delivering better value to customers (Womack, Jones, & Roos, 1990). Over the years, lean manufacturing systems and environmentally sustainable initiatives have been proven to be positively correlated (Chiarini, 2014; King & Lenox, 2001) and to have synergistic results on operational and environmental performance (Amani, Lindbom, Sundström, & Östergren, 2015). Gibson, Yoke San, Pham, Pham, and Thomas (2008) point out that adopting a process management strategy such as lean manufacturing system allows industries to achieve bottom line savings in the production process and improve efficiency which will form a platform to achieve economic sustainability. Dhingra, Kress, and Upreti (2014) point out that green initiatives undoubtedly lead towards sustainability and Amani, et al. (2015) highlight the importance of sustainability not just as government and public interest also for businesses to improve their efficiency and thereby gain competitive edge over others.

Within this context, the authors have undertaken a review of lean thinking practice literature to consider how such practices have influenced sustainable business practice over the last two decades. We present the review methodology and discuss the results, which revealed two main areas of influence: a) lean manufacturing tools and environmental performance; and b) lean and green business process management. Considering this, key research questions addressed in this study are:

- What lean tools/ practices can be applied to environmental sustainability work streams (e.g.: waste management, energy management, emission management, water management and chemical management)?

- What lean and green models or approaches are being used for lean and green business process management?

## 2. Research Method

The literature review was conducted in three phases of extraction, analysis and interpretation (Levy & Ellis, 2006; Webster & Watson, 2002). The initial extraction phase entailed a systematic search, identification and extraction of the resources relevant for the scope of the review. In order to extract the literature a methodical search was conducted to identify the relevant articles and extracted key findings pertinent for the review. Then appropriate categorization and a coding scheme were designed to carry out the analysis to meet the review objectives. The final stage involved synthesizing the coded outcomes and producing descriptive findings and summary tables. A comprehensive evaluation revealed a number of links and relationships among lean management and sustainable business practice.

An extensive literature review is fundamental step in forming a field of research and is the platform for extending knowledge and building theory (Webster & Watson, 2002). Therefore integration of interpretation and analysis plays a significant role so it could underpin the research question (Easterby-

Smith, Thorpe, & Jackson, 2012). This qualitative method has already been used in similar research area including lean production (Moyano-Fuentes, Sacristán-Díaz, & Martínez-Jurado, 2012) lean and green (Garza-Reyes, 2015) and sustainability (Seuring, Müller, Westhaus, & Morana, 2005). Throughout the main phases of the literature review a sequence 'select, know, comprehend, apply, analyse, synthesise and evaluate' was followed as suggested by Levy and Ellis (2006) to ensure the literature review to be structured and effective.

### *2.1 Extraction of relevant papers*

A systematic review of literature considered two main criteria to clarify the locations of articles and the search strategy. The revised bibliography contains peer reviewed journal papers and conference papers. Saunders, Lewis, and Thornhill (2012) describe peer reviewed journal papers as most useful of all primary and secondary literature sources and conference proceedings as very useful (if on the theme research) to critically review the literature. Unpublished working papers, industry reports, magazines and dissertations were excluded. To provide background for the themes some paradigmatic books were used, but for the analysis only journal articles and conference papers were used. Journal papers were extracted from numerous electronic databases to acquire a deep insight on the links between lean and green concepts, discover knowledge on lean and green models and potential future research areas. Most of the articles were found through Science direct, ABI/inform and Google scholar as these databases accommodated a large range of scholarly articles. However other databases were also checked as they are the publisher of most of the popular journals in this research filed. This was done to ensure that important articles will not be overlooked during the resource extraction phase.

Papers were identified from academically refereed full text journal publications in bibliographic databases, spanning two decades from 1995. This time period was chosen to align with the Cleaner Production conference reflective timeframe, to consider any emergent themes and patterns of concepts in the field. As this is an interdisciplinary review it was important to look at both business and science databases to fit into the selected scope of the review. The search strategy was formulated after identifying sources and key words, synonyms and related terms for the search, as summarised in Table 1. The key terms "sustainable business practice" and "lean thinking" embraces an extensive range of sub-topics and therefore a significant number of search strings were required. These encapsulated definition, synergistic relationships, tools, techniques and practices and industrial case studies. Other critical concepts related to key words were also used in search strings to identify other possible links.

**Table 1:** Key words used in searches

| Lean thinking | Sustainability | Lean and green model | Industry |
|---|---|---|---|
| Lean | Green | Lean and sustainability | Sector |
| Lean Management | Sustainable business practice | Lean and green approach | Business |
| Lean Production | Waste Management | Lean and green operations | Manufacturing |
| Lean Manufacturing | Eco-Efficiency | Lean and green manufacturing | |
| Toyota Production System | Environment | Lean and green framework | |
| Lean construction system | Environmental Impacts | Lean and sustainable | |
| | Emissions | Green manufacturing | |
| | Energy Efficiency | Lean and green agenda | |
| | Ecology | Lean green | |
| | Water management | Environmental lean | |
| | Chemical management | Lean eco-efficiency | |
| | Environmental sustainability | Lean eco sustainability | |
| | Sustainability culture | | |
| | Cleaner production | | |
| | Environmental stewardship | | |

A backward review process was conducted, going back to relevant citations of the extracted articles to determine preceding articles related to the scope of the review. This was followed by a forward review to determine subsequent articles which cited the extracted articles that are within the review theme, to access the relatively extensive amount of literature (Webster & Watson, 2002). The search terms were listed considering the phenomena which needed to delve further.

The C-I-M-O context-intervention-mechanism-outcome (Briner & Denyer, 2012) framework was used for this stage to identify the inclusion and exclusion criteria for the study. The search strings such as lean green, lean and green model, lean and sustainability, lean and environmental sustainability, lean and sustainable practice, lean-eco sustainability etc. were used following the key words given in Table 1. When the same articles repeatedly appeared this was considered to be the saturation point. In addition all the articles were manually checked through the abstracts to ensure that the paper fit the scope of the study. This helped in omitting papers that did not address the lean and green concepts or which were external to the defined scope. After carrying out a rigorous search, 90 articles were used for coding and analysis.

The NVivo software was used, which is considered as one of the most powerful tools in managing, visualising and analysing qualitative data (Bazeley & Jackson, 2013). The review methodology is summarised in Table 2. A protocol was developed articulating the process for analysis and support activities. This included the codification system and the guidelines for the application of NVivo for this qualitative analysis. Early determination of what is important to capture and record is a critical step for efficient archival analysis (Okoli & Schabram, 2010).

**Table 2:** Review methodology

| Phase of the Literature review | Objective | Method | Tool |
|---|---|---|---|
| **Formulate research question** | The research question will be used as guiding statement to conduct the study | • Analysing highly cited journal articles in lean and green research field and identifying gaps | Backward and forward review |
| **Selecting sources** | Selecting relevant databases and extract relevant articles and evaluation | • Define the relevant databases | Science Direct (Elsevier), ABI Inform Global (ProQuest Direct), EBSCOhost databases, Wiley Online Library (Wiley), Emerald Insight, Scopus, Web of Science, Google scholar |
| **Selecting article and evaluation** | | • Define the time span of research papers<br>• Define criteria and search strings | 1995-2015<br>*Inclusion criteria*- Lean terms with green, environment, sustainability, eco-manufacturing etc. Search strings were constructed using key words presented in table 1. Peer reviewed journal papers and conference papers (paradigmatic books were used to provide background)<br>*Exclusion criteria*- Unpublished working papers, industry reports, text books, dissertations and magazines |
| **Analysis and synthesis of results** | Analysing and synthesising the results | • Selection of method for analysing the qualitative data<br>• Coding and synthesising data | Descriptive findings<br>Visual representation of data<br>Thematic analysis<br>NVivo software |
| **Interpreting and reporting the results** | Reporting and interpreting the outcome | • Critically analysing literature and encapsulating meta data from literature, and linking lean with sustainable business practices | Summary tables, matrix table |

### *2.2 Analysis and synthesis*

Given that the purpose of this research was to deliver a synthesized review of how lean thinking could be used as a targeted intervention for sustainable business practice, the pre-codification scheme was based on the fundamental questions of *what*, *why*, *who* and *how*, for understanding the incorporation of lean and green paradigms. The research perspective was underpinned by theoretical contexts and research methods. This was consistent with previous similar meta-literature review papers (Garza-Reyes, 2015) which created a base to investigate common themes reported in environmental management field and major analysis on lean and green concepts.

## 3. Descriptive analysis of findings

Of the 90 articles selected for review, 89% (80 articles) were journal articles and 11% (10 articles) were conference papers. The range and frequency of journals containing the reviewed content are summarised in Figure 1. There is a significant proportion of 26% (21articles) of the journal articles published in the *International Journal of Cleaner Production*. About 5% (4 articles) were published through *Environmental Quality Management Journal*, followed by the *Benchmarking and Production Operation Management journal* (4%, 3 articles). This provides an indication of suitable outlets to publish lean and green related articles and shows International Journal of Cleaner Production has significantly contributed to this field of lean and green thinking.

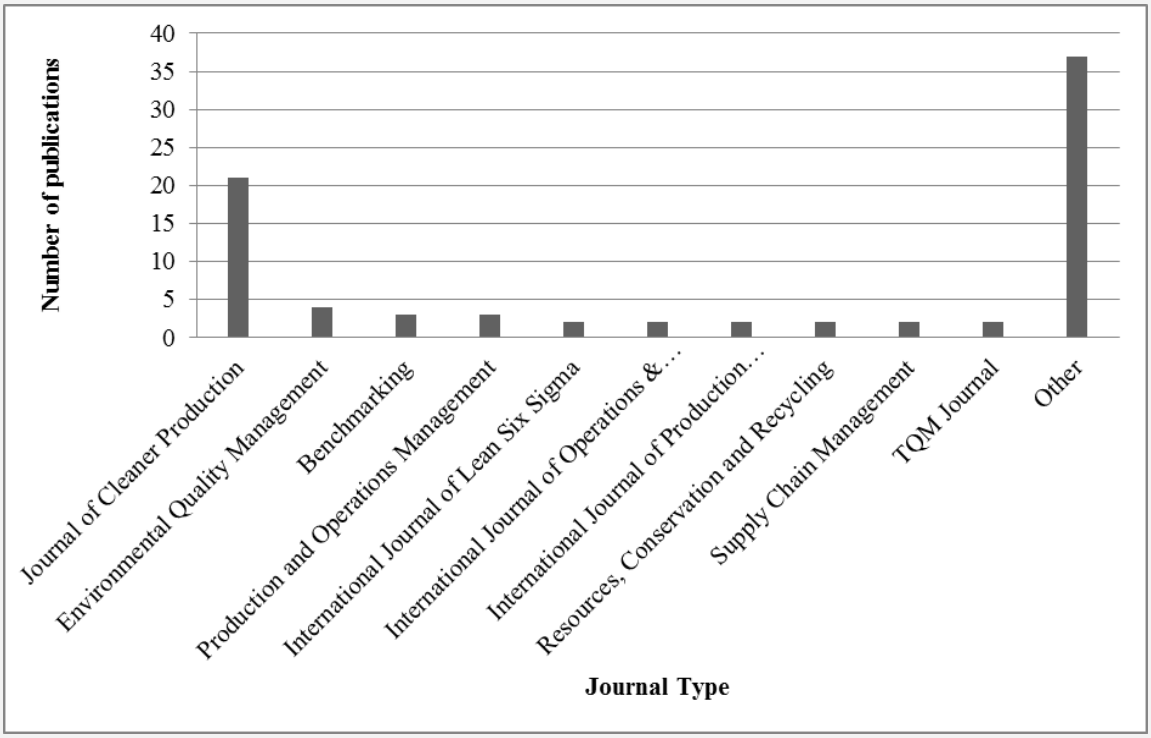


**Figure 1:** No. of articles published in different journals

Figure 2 summarises the number of publications chronologically over the period since 1995. There is an increasing trend on articles from 2010 onwards as 81% of articles were published from 2010 onwards of the analysed resources from the time period of 1995-2015. This highlights the comparatively novel nature of this field of research, with an emerging narrative about this concept.

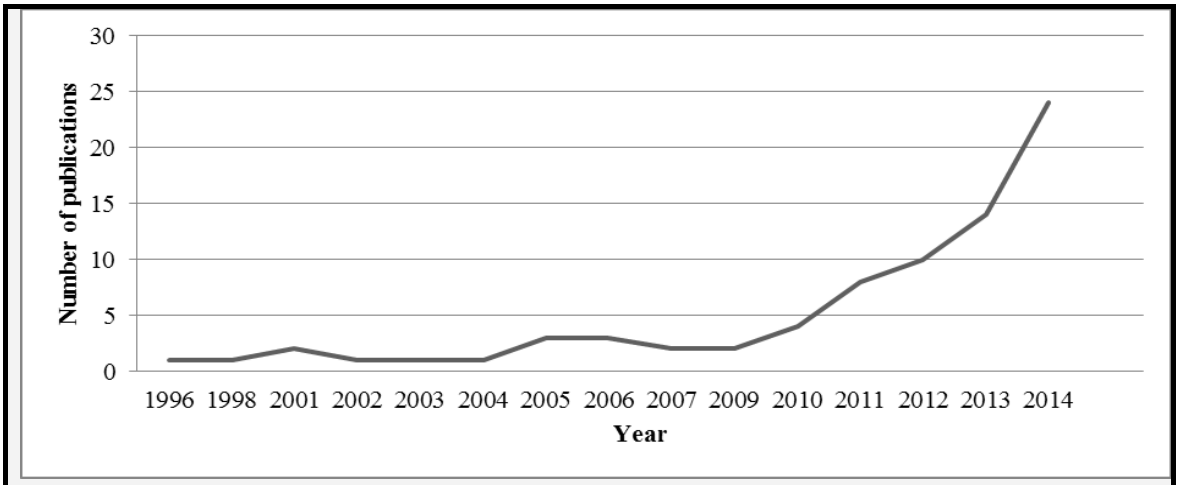


**Figure 2:** Articles published vs year

Even though some articles disclosed the location of the case study, some studies gave a generic name by to the case study according to the type of the industry. As first and the second authors are the main contributors for the paper it could be an appropriate way to determine the geography of the publication content. Figure 3 shows the demographic distribution and number of the articles by the first authors. The country of the second author was also analysed, showing only minor changes in the proportions of publication by country. In most publications both first and second author were from the same country.


**Figure 3:** Geographic distribution of research conducted on lean and green (by first author)

When considering the distribution in developed and developing countries by economy (according to the UN country classification system) a higher percentage, 80% (n=72) of the publications was recorded from developed countries. It is evident that a largest proportion 29% of literature was recorded in USA and second highest 12% in UK. 20% (n=18) developing countries recorded were namely; Malaysia, India, Brazil, China, Indonesia, Singapore and Turkey. This is a good indication that the research findings were also likely to be applied to industries in these countries.

Figure 4 presents the articles analysed according to their industrial application. Out of 90 publications 25 were theoretical papers and the rest of the 65 articles had different industrial case studies or different industries where the empirical data were gathered from. There were industrial applications such as manufacturing as a whole, automotive, construction, metal work, multi sectoral, food, rubber logistics and other. Multisector referred to publications which had more than one case study or industrial application could be widely applied for multisector (Piercy & Rich, 2015; Verrier, Rose, Caillaud, & Remita, 2014). Other industries consist of one publication each from industries namely; aerospace, education, furniture, paper and board.

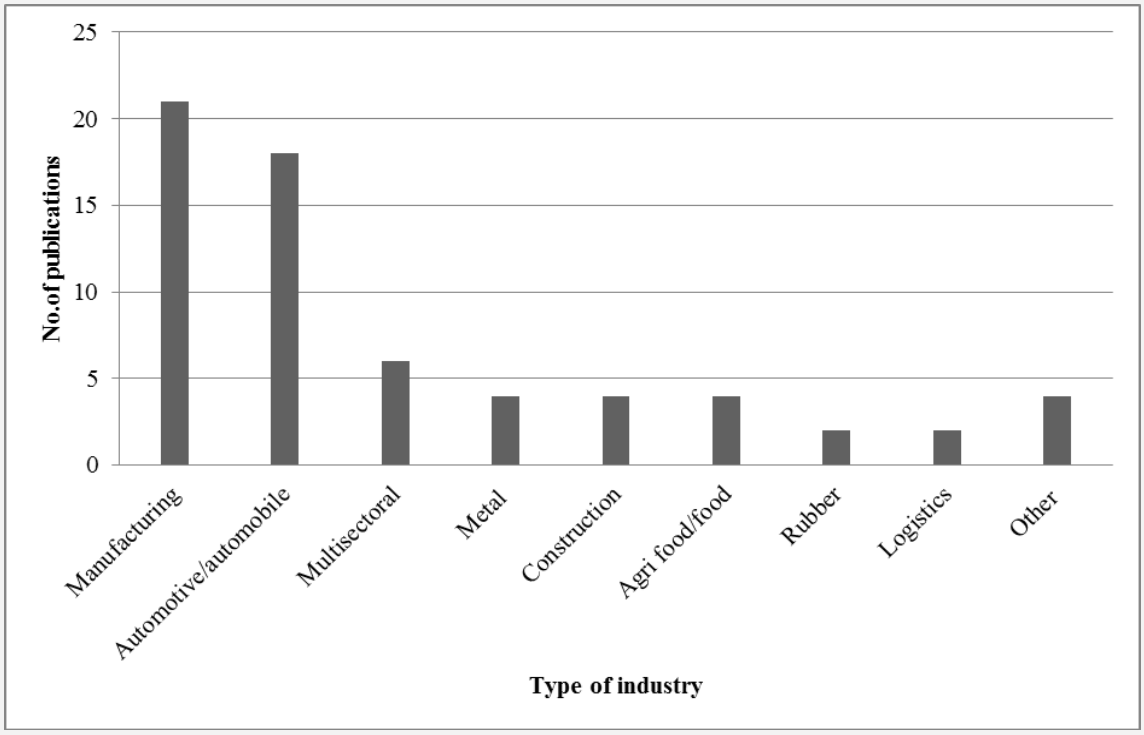


**Figure 4:** Number of articles by the industrial application

33% (n=23) of the articles were conducted for a manufacturing industry and the 28% (n=18) was recorded in the automobile industry. However there were other articles emerging from sectors such as construction (Banawi & Bilec, 2014; Ogunbiyi, Adebayo, & Goulding, 2014), metal (D'Errico, Perricone, & Oppio, 2009), agri-food/food (Chaplin & Simon, 2014) , rubber(Govindan, Kannan, & Shankar, 2014) and logistics (Cosimato & Troisi, 2015).

## 4. Discussion

This section discusses findings from the analysed literature; relationships between lean and green concepts; lean tools and sustainable business practices; and different types of lean and green models and approaches.

### *4.1 Relationship between lean and green concepts*

Sustainability is becoming a key priority in contemporary society, not only because of the public and government requirement but also for the benefits of the firms in increasing efficiency (Amani, et al., 2015). From the inception of lean and green concepts during the studied period of 1995-2005, the move towards environmentally conscious manufacturing was discussed by Florida (1996a) who found the infusion of lean and green in terms of advanced production mechanisms and innovative methods for green manufacturing. This research identified enterprises that are interested in using innovation in their manufacturing activities tend to be creative in tackling environmental risks by implementing green design, improving productivity and engaging in continuous improvements. King and Lenox (2001) showed empirical evidence on lean production having positive correlation with waste minimisation and pollution prevention. Rothenberg, Pil, and Maxwell (2001) found that elements such as buffer minimisation, work systems and human resource practices in lean thinking will entail management practices that are facilitative in efficient use of resources.

Bandehnezhad, Zailani, and Fernando (2012) presented survey results on how lean approach is connected with functional aspects of process and equipment, people, product design and customer satisfaction which derive positive impact on environmental performance. Miller, Pawloski, and Standridge (2010) stated that simultaneous implementation of lean and green yield significant results on multiple parameters in operational performance. Yang, Hong, and Modi (2011) pointed out that the main purpose of lean practice, which is reducing process waste should be expanded to address environmental waste generation

and to improve environmental performance by means of establishing environmental management practices. It is vital for industries to practice lean management and environmental sustainability initiatives to yield the eco-advantages which will allow the firms to enjoy both economic and environmental benefits. Amani, et al. (2015) examined potential synergy between lean philosophy and green initiatives in improving the resource efficiency in food sector. It was found that a context specific lean six sigma root cause analysis method is conducive in improving efficiency. Bergmiller and McCright (2009) stated that models in lean and green context contains management system, identification of waste and establishing waste reducing techniques and affirmed that the strength level of a management system has correlation with waste reduction techniques with consequence for firm's lean and green programmes. Dües, Tan, and Lim (2013) showed the advantage of lean practice in implementing green initiatives and in converse green activities having positive effects on current lean approaches. As shown by many authors above, integration lean and green appears to be a promising coupled approach in achieving economic and environmental benefits in modern industry.

### *4.2 Lean tools and practices*

Recently, researchers have shown an increased interest in different lean tools and practices which can positively influence sustainable business practices. Table 3 summarises the literature references on lean tools and practices which have positive impacts on improving environmental performance and thereby facilitate sustainable business practice.

**Table 3:** Effects of lean tools and practices on environmental performance

| Lean tool/lean practice | Author and Year | Impact on environmental performance |
|---|---|---|
| **5S** | Vais, Miron, Pedersen, and Folke (2006), Fliedner (2008), Chiarini (2014) | Improve resource productivity, waste management and energy efficiency |
| **Employee involvement** | Maxwell, Briscoe, Schenk, and Rothenberg (1998), Rothenberg, et al. (2001), Soltero and Waldrip (2002), Simpson and Power (2005b) | Effective implementation of environmental sustainability initiatives |
| **Adaptation of corporate culture** | Mollenkopf, Stolze, Tate, and Ueltschy (2010) | Support from top management to implement sustainability culture |
| **Buffer level** | King and Lenox (2001) | Improve waste management and reduce pollution |
| **Cellular manufacturing** | Fliedner (2008), Bandehnezhad, et al. (2012), Chiarini (2014) | Improve waste management and energy efficiency |
| **Kaizen events** | Rothenberg, et al. (2001), Soltero and Waldrip (2002),Vais, et al. (2006), , Miller, et al. (2010),Pampanelli, Found, and Bernardes (2014),Hong, Ga Yang, and D. Dobrzykowski (2014) | Improve waste, water and chemical management, resource optimisation and energy efficiency |
| **Quality circles** | Maxwell, et al. (1998) | Innovative ideas to improve sustainability, waste reduction, high employee engagement which leads to effective implementation of environmental sustainability initiatives |
| **Inventory reduction** | King and Lenox (2001), Rothenberg, et al. (2001),Venkat and Wakeland (2006) | Improve resource productivity and waste management, reduce energy usage and emissions by transport |
| **Lean product flow** | Ball (2015) | Improve energy efficiency |
| **Lean supply chain management** | Simpson and Power (2005a), Fliedner (2008), González-Benito and González-Benito (2008), Miller, et al. (2010) | Improve waste management across the network by collaborating with the suppliers |
| **Total Productive Maintenance (TPM)** | Fliedner (2008), Chiarini (2014),Piercy and Rich (2015) | Improve resource productivity, waste management, chemical management and energy efficiency |
| **Value stream mapping (VSM)** | Simons and Mason (2003) Fliedner (2008), Vinodh, Arvind, and Somanaathan (2011), Faulkner and Badurdeen (2014), Brown, Amundson, and Badurdeen (2014) | Identifying environmental impacts and assessing areas to be improved and improve energy efficiency and waste management |
| **Pull approach** | Fliedner (2008) | Improve waste management and energy efficiency |
| **Six sigma** | Fliedner (2008) | Improve waste management and energy efficiency |
| **Pre-production planning** | Fliedner (2008) | Reduce waste by planning for a greener manufacturing process |

Table 4 summarises the literature discourse on how "lean *integrated* tools/practices" can reduce environmental impacts.

**Table 4:** Effects of lean *integrated* tools and practices on environmental performance

| Lean integrated methods/tools/practices | Author and Year | Action | Impact on environmental performance |
|---|---|---|---|

| | | | |
|---|---|---|---|
| **Sustainable value stream mapping (Sus-VSM)** | Faulkner and Badurdeen (2014), Brown, et al. (2014) | Assess and monitor; energy, water consumption and GHG emissions, and areas of improvement will be suggested. | Assess energy, water greenhouse gas emissions, noise levels, waste and water measurements and address areas of improvement |
| **Green value stream mapping** | Marimin, Darmawan, Machfud, Islam Fajar Putra, and Wiguna (2014) | Green value stream defines seven sources of waste generation as the excessive use of energy, water, material, waste, transport, emissions, and damage to biodiversity | Identify green waste other than lean waste and investigate on areas of improvement |
| **Waste flow mapping** | Kurdve, Shahbazi, Wendin, Bengtsson, and Wiktorsson (2015) | Reducing material losses and inefficiencies in the handling of materials and waste. | Identify waste material efficiency potentials |

### *4.3 Discussion of lean methods and environmental management*

In this section, we highlight lean tools/principles and practices associated with sustainable business practices under key work streams such as waste management, energy management, emission management, water management, chemical management and green supply chain management. Table 5 presents a matrix table between lean and lean integrated tools/practices and environmental management work streams which are further elaborated in the following sub-sections.

**Table 5:** Lean and lean integrated tools/practice and environmental management work stream matrix

| **Lean and lean integrated tools/practices** / **Environmental management work streams** | **Employee engagement** | **Value stream mapping** | **Total Productive Maintenance** | **Sustainable value stream mapping** | **Green value stream mapping** | **Kaizen** | **5S** | **Inventory reduction** | **Cellular manufacturing** | **Lean product flow** | **Pull approach** | **Lean six sigma** | **Buffer level** | **Lean supply chain management** | **Pre-production planning** | **Quality circles** | **Lean six sigma and root cause analysis** | **Waste flow mapping** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Waste management | ● | ● | ● | ● | ● | ● | ● | ● | ● | | ● | ● | ● | ● | ● | ● | ● | ● |
| Energy management | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | | | | | |
| Emission management | ● | ● | ● | ● | ● | | | ● | | ● | | | | | | | | |
| Water management | ● | ● | | ● | ● | ● | | | | | | | | | | | | |
| Chemical management | ● | | ● | | | ● | ● | | | | | | | | | | | |

#### 4.3.1 Lean methods and waste management

In general, industry adopt waste management practices which include steps of ‘reduce, reuse and recycle’ towards minimising landfill waste (Schaper, 2002). The majority of environmental initiatives in existing business scenario are end of pipe treatments. Many small enterprises are resistant to be proactive and embark on sustainability measures due to major capital costs incurred in changing raw materials or process designs and thereby end up implementing ad-hoc solutions (Hillary, 2000).

Ōno (1988) defined “lean manufacturing” as a business strategy that mainly focus on reducing non-value

adding waste such as transport, inventory, motion, waiting, over production, over processing and defects. Florida (1996b) was one of the first authors who discussed lean and green concepts during the study period of 1995-2015. Florida (1996a) showed that the fundamental principle of lean management is to add more value to the customers by omitting non-valued activities from the value chain. The main purpose is to eliminate waste, optimize resources, which can be directly linked to critical environmental issues such as pollution. Lean focus is on achieving high quality standards throughout the process, not merely solving a problem when it arises, as a short term measure will not sustain in the long run. Environmental impacts of a manufacturing process should also be anticipated beforehand and must adopt proactive measures to prevent irreversible consequences. This is consistent with the cleaner production concept of addressing the waste at the point of generation (King & Lenox, 2001; Sawhney, Teparakul, Bagchi, & Li, 2007).

Bergmiller and McCright (2011) proposed a holistic waste reduction programme synergising green and lean programmes which provide advantage in delivering better business results. Cleaning up the dirty dozen of waste: seven from lean programme (transport, inventory, motion, waiting, over production, over processing and defects) and five from green programme (water waste, hazardous waste, energy waste, solid waste, and greenhouse gases) have synergistic effects on integrated waste management system. Different mapping tools such as green value stream mapping (Marimin, et al., 2014), waste flow mapping (Kurdve, et al., 2015), process mapping (White & James, 2014) were found to observe and visualise the point of generation of green waste. These mapping tools are effective in evaluating environmental impact caused by the process activities. These mapping tools can be amalgamated with life cycle assessment (LCA) as it evaluates potential environmental impacts associated with the inputs and outputs at each phase of the process. The scope of it can be defined according to the accessibility of data in the process. Other specific tools such as calculation of ecological footprint of a product will be an effective quantitative parameter to assess as the area of land required to extract resources and emit waste when producing it. In this ways incorporation of lean tools and green waste management can yield better results in reducing financial costs and negative environmental impacts. Several authors provided evidence on positive effects of lean and green combination on waste management (Folinas, Aidonis, Triantafillou, & Malindretos, 2013; Galeazzo, Furlan, & Vinelli, 2014) and some authors used case studies to further demonstrate quantitative results in waste reduction (Amani, et al., 2015).

5S is conducive in creating a clean work environment, minimising waste by early detection of spills, leaks and encouraging employees to dispose waste systematically (Chiarini, 2014; Fliedner, 2008; Vais, et al., 2006). Total productive maintenance (TPM) support environmental management (Vais, et al., 2006) and is advantageous in reducing several impacts caused by machine operations such as; reducing leakage of oil and emissions of dusts, and chemical fumes to the environment (Chiarini, 2014). Value stream mapping is useful in determining the environmental impacts in the manufacturing process (Brown, et al., 2014; Chiarini, 2014; Esfandyari, Härter, Javied, & Franke, 2015) and to improve environmental performance through reducing the scrap material and defects (Fliedner, 2008). However, Sobral, Sousa Jabbour, and Chiappetta Jabbour (2013) showed that even though the companies believe practicing lean could improve environmental performance the is a lack of a holistic approach in attaining synergistic results. For examples industry does not capitalise on the association between value stream mapping and life cycle analysis. As an extensive approach Faulkner and Badurdeen (2014) presented a Sustainable value stream mapping, comprehensive methodology to further develop value stream mapping by recognising suitable metrics and methods to visually present environmental waste. Brown, et al. (2014) distinguished the features of a traditional value stream mapping and a sustainable value stream mapping by pointing out that sustainable values stream mapping address raw material waste, process water waste, energy waste under environmental metrics which was not captured in the traditional value stream mapping.

Kaizen is an approach supporting continuous improvement and it facilitates activities in minimising material waste and pollution (Miller, et al., 2010; Pampanelli, et al., 2014; Vinodh, et al., 2011). This approach can be integrated with Environmental Management Systems (ISO 14001) in sustainable business practices as continuous improvement plays a key role in it as well. Quality circles play a key role in identifying issues in the process from employees and getting innovative solution from them (Maxwell, et al., 1998). Participation of people is considered to be a critical factor in implementing lean management system (Amani, et al., 2015; King & Lenox, 2001; Maxwell, et al., 1998; Soltero & Waldrip, 2002), likewise "people involvement" is imperative in carrying out environmental practices (Rothenberg, et al., 2001). This process is useful in effective implementation of initiatives as the employees have ownership in implementing their own idea. Even in sustainable business practice having quality circles to analyse problems and by brainstorming or by using "cause effect diagrams" will be useful. Furthermore

champions could be selected from these lean quality circles and sustainability circles based on the creativity of the solutions they present. They could be recognised and rewarded for implementing those solutions. Thereby the execution their ideas could be assured.

### 4.3.2 Lean methods and energy management

Moscardo (2013) showed that energy management requires behavioural changes in people (to reduce wasteful energy usage) and energy efficient technologies (e.g.: installation of energy efficient appliances, improve lighting systems while maximum utilisation of natural light, green building designs, zero emission transport, use of renewable energy solutions etc.). Moscardo (2013) highlighted the importance of shifting from fossil fuel to renewable energy such as hydro, geothermal, wind, solar and biomass power which are sustainable energy solutions.

Rothenberg, et al. (2001) showed that efficient use of energy and lean practices are positively correlated. Several lean tools such as cellular manufacturing, lean product flow, total productive maintenance, 5S and value stream mapping (Table 5) have positive effects on efficient energy management. Cellular manufacturing leads to decrease in energy by means of lower set up times and lesser product changeover. Furthermore reduced inventories demand less floor spacing which reduces the energy consumption. (Bandehnezhad, et al., 2012; Chiarini, 2014). Few authors identified the importance of lean integrated tools such as sustainable value stream mapping which used an energy metric to monitor and evaluate the energy usage in processes (Brown, et al., 2014; Faulkner & Badurdeen, 2014). After inquiring further Chiarini (2014) showed quantitative results on lean tools having positive impact on energy management by proving a positive correlation between 5S and energy efficiency due to reduced space in manufacturing functions. Similarly using total productive maintenance also showed decreased energy consumption. Using lean tools such as Kaizen (Pampanelli, et al., 2014), value stream mapping (Folinas, Aidonis, Malindretos, Voulgarakis, & Triantafillou, 2014) authors suggested systematic approaches which significantly reduced energy consumption. Ball (2015) investigated the effects of lean product flow on energy consumption and found that a significant financial savings could be made not only at the point of occurrence of energy usage but as a complete lifecycle (e.g.: heat that was produced as waste in one process can be re-used to another process). As the primary objective of business is profit maximisation in neo classical economic system, quantifying the benefits in monetary terms is appealing to industrialists. With the increasing prices in fuel and energy, making substantial energy reductions will lead to win- win situation to both economic and environmental performance in business enterprises.

### 4.3.3 Lean methods and emission management

According to IEA (2007) nearly 31% of global primary energy is consumed by the manufacturing industry. This can be directly linked to carbon emission and climate change which is a global environmental concern. On the other hand combustion of fossil fuel such as coal, fuel and natural gas will cause emission of carbon monoxide, sulphur dioxide, nitrous oxide and heavy metals. Hence it is essential to adopt clean technologies and shift to renewable energy options. In order to manage emissions, strategies and tools such as carbon footprint analysis, strategic assessment of climate risks and opportunities, energy efficient measures, renewable energy use, emission trading and investing in carbon credits were suggested (Moscardo, 2013).

King and Lenox (2001) provided empirical evidence on reduction of emissions as an effect of lean production. Rothenberg, et al. (2001) indicated that lean practices and reduction of volatile organic compounds are negatively related through the empirical data gathered by surveys and interviews. Azevedo, Carvalho, Duarte, and Cruz-Machado (2012) pointed out that carbon taxes has direct impact on economic and environmental performance. When environmental taxes were imposed on businesses in terms of increasing fuel prices, this led to increased price in products. This was enacted with the aim of reducing greenhouses gas emissions. An immediate reduction in greenhouse gas emission is necessary as adaptation and mitigation measures for climate change.

Ball (2015) investigated the use of flow principle in decreasing energy utilisation which also led to reduction of gaseous emissions. Chiarini (2014), found that total productive maintenance supports to reduce emissions of dust and chemical fumes into the environment. Wu, Low, and Jin (2013) recommended to follow a value stream mapping to identify non-value adding components in the process and the employees in industry should be trained to conduct a smooth workflow which will lead to reduction in carbon emissions. As an extension of value stream mapping Faulkner and Badurdeen (2014)

noted the importance of using energy metrics in "sustainable value stream mapping" as it is directly linked to the emission of greenhouse gases. Simons and Mason (2003) showed that sustainable value stream mapping can lead to, end-to-end (from raw material to product) carbon dioxide reduction. Ng, Low, and Song (2015) suggested a carbon- value efficiency methodology which infused value stream mapping and Kaizen showed a significant improvement in carbon value efficiency and reduction in carbon footprint.

In contradiction Venkat and Wakeland (2006) showed that lean supply chains are not necessarily green; even though "reduction of inventory levels" results in minimising emissions, "frequent replenishment" raise the carbon dioxide emissions due to increase in transport. This shows that not all lean tools and practices are green and organizations should deliberately choose these tools when integrating to sustainable business practice. Rothenberg, et al. (2001) pointed out that trade-offs between lean and green are unavoidable. For example painting cars in batches of similar colour will minimise emissions. In converse lean approach will use spray paint to obtain better quality and efficiency which has negative effects on the environment. However Rothenberg, et al. (2001) showed that some lean firms are willing to compromise on some lean practices to mitigate their emissions.

**4.3.4 Lean methods and water management**

"Water efficiency" approaches can minimise the rate of water consumption in industries. By reducing pollution during the process, increase the capacity of water for reuse and reduce waste water. Raising awareness on sustainable water management among employees and training them continuously will ensure the appropriate use of "water efficiency" and "pollution prevention" approaches (Byers, Lindgren, Noling, & Peters, 2010).

Vais, et al. (2006) pointed out that Kaizen focus on continuous improvement and Kaizen workshops and trainings have caused people to changes their attitudes toward proper housekeeping and 3R (reduce, reuse, recycle). By inculcating that culture, employees are motivated to use recycled process water, to responsibly consume and discharge water. Folinas, et al. (2014) suggested a systematic approach using value stream mapping technique to measure water consumption. However this lacks a proper monitoring and continuous improvement in water efficiency and hence sustainable value stream mapping was developed including water metrics. This monitors the water consumption level during manufacturing activities and represents important areas to evaluate and to be considered for improvement (Brown, et al., 2014; Faulkner and Badurdeen (2014)).

Integrated lean and sustainable water management practices could be improved further by amalgamating sustainable corporate environmental initiatives such as assessment of water consumption (e.g.: central water metering, sub metering), sustainable sourcing of water, treatment of waste water, re-use of treated waste water for other purposes such as gardening toilet flushing, installing water efficient fittings, rain water harvesting, drip irrigation for landscaping, raising awareness and training employees etc.

**4.3.5. Lean methods and chemical management**

In the past years restricted substance list has attracted much attention while sustainable businesses orient towards green chemistry. Many manufacturers were challenged by these restricted substance list which were found in the chemicals and raw material they used for their production process as those are toxic for humans and environment (Das, 2013). Organizations should ensure safety of people and environment through proactively understanding and prudently selecting every chemical and raw material used in their manufacturing process.

5S is a popular practice in many organizations which is conducive in creating a cleaner and a methodical work place. Bandehnezhad, et al. (2012) described 5S as an approach for organizing the work environment in a better way, and to identify spills and leaks which is important in reducing chemical and material usage. Chiarini (2014) showed how total productive maintenance could be used to reduce impacts on machines such as oil leakage, emissions of dust and chemical gases to the environment. Pampanelli, et al. (2014) showed how Kaizen events caused considerable reduction of general chemical products consumption when applying lean and green model for production cell. Kaizen is an approach for continuous improvement and this concept is the underlying principle for environmental management system as well. This shows similar core concepts in both lean and green thinking.

### 4.3.6 Lean methods and green supply chain management

Lean, green and supply chain management was discussed by several authors in the past and state-of -art literature reviews were published with regard to links between lean, green and supply chain management. Mollenkopf, et al. (2010) investigated literature and found drivers, barriers, converging and contradictory points across green lean and global supply chains. Lean supply chain management plays a key role in implementing environmental sustainability initiatives across supply chain and finally to deliver all potential advantages of a green supply chain management strategy (Mollenkopf, et al., 2010). Martínez-Jurado and Moyano-Fuentes (2014) assessed the literature on the relationships between lean management, supply chain management and sustainability and classified literature along with empirical evidence. Azevedo, et al. (2012) highlighted that firms implement lean and green paradigms to manage their supply chain for this purpose they presented a theoretical framework to analyse the effect of green lean upstream supply chain management on sustainable development. Wiengarten, Fynes, and Onofrei (2013) showed that there are possible synergistic effect between environmental and quality/lean practices in supply chains.

### *4.4 Lean and green model/ approaches and frameworks*

In recent years, there has been an increasing amount of literature on lean and green models, approaches to integrate lean and green and paradigms. A number of studies analysed literature and developed conceptual models and some of them were validated with case studies. Out of those models, several attempts have been made to numerically construct optimisation or simulation model. Table 6 encapsulates the literature on conceptual, empirical and validated conceptual model/ approaches and frameworks.

**Table 6:** A summary of lean and green models and approaches found in the literature

| Proposed model | Model Type * | Context |
|---|---|---|
| **Optimization model** | Validated conceptual | Specific-Cyclic pallet system |
| **SIRIM Green 5-S Model for Sustainable Development/Integrated Lean Management System Model** | Validated conceptual | General |
| **Model which indicates the relationship between Green Lean Six Sigma (GLSS) and Financial Performance (FP)** | Conceptual | Specific- automotive industry |
| **Integrated Lean, Agile, Resilient and Green (LARG) analytic network process (ANP) model to support decision-making** | Validated conceptual | Specific-automotive supply chain |
| **Simulation model** | Conceptual | General- for generic supply chain |
| **Lean-ecosphere' management system- using interpretive structural modeling (ISM) and analytical network process (ANP).** | Validated conceptual | Specific- manufacturing semiconductor |
| **Simulation model** | Validated conceptual | Port |
| **Interpretive structural modeling approach** | Conceptual | Automotive supply chain |
| **Conceptual framework** | Validated conceptual | Automotive |
| **Interoperability analysis model** | Validated conceptual | Automotive |
| **The model of efficient and sustainable improvements in a lean production system** | Validated conceptual | Forming tube company |
| **Lean & Green Model** | Validated conceptual | Automotive |
| **An approach for incorporating both lean and green strategies into a manufacturing system** | Validated conceptual | Automotive |
| **Model incorporating lean and green supply chain into a performance measurement system, using the balanced scorecard approach** | Conceptual | Supply chain |
| **A supply chain planning model** | Validated conceptual | Manufacturing- tank, cylinders and containers |
| **Carbon-Value Efficiency (CVE)** | Validated conceptual | Metal stamp part producer |

| | | |
|---|---|---|
| **A stage-based theoretical model of lean-sustainability** | Validated conceptual | Multisector |
| **Environmentally Lean (En-Lean) methodology** | Validated conceptual | Metal cutting industry |
| **A conceptual model with lean, agile, resilient and green practices and supply chain management attributes** | Conceptual | Supply chain |
| **Integrated lean tools and sustainability concepts with discrete event simulation modeling** | Validated conceptual | Furniture industry |
| **Structural model** | Validated conceptual | Manufacturing |
| **Integrated sustainable practices model incorporating the most popular lean, green, and social practices** | Validated conceptual | Auto fashion |

** 1. Conceptual = composition of concepts, which are used to help people know, understand, or simulate a subject; 2. Validated Conceptual = conceptual model being validated for a particular application/case study or tested with empirical evidence from industry*

At the outset of developing green and lean models it is important to identify the overlapping sections of both practices to achieve the best cumulative results in environmental and economic performance. Dües, et al. (2013) stated common attributes such as waste, waste reduction techniques, people and organization, lead time reduction, supply chain relationship, KPI: service level which lies in the intersection of the two subsets of lean and green. Based on selected attributes number of authors developed conceptual models and some authors validated their conceptual models by obtaining empirical data. This section of the review analysed 22 articles on lean and green models/frameworks and approaches which included 5 conceptual models and 17 validated conceptual models (Table 6). In most cases the conceptualised models were validated in a specific industrial context, where majority of these were from automobile industry (32%) and manufacturing industry (27%). This high proportion in automobile and manufacturing field in general can be justified as the lean manufacturing system/Toyota manufacturing system originated from automobile context. After successful implementation of lean manufacturing system in these industries, they have taken leadership in incorporating environmental sustainability aspect into lean thinking. The third highest numbers of models (18%) were applied to supply chain context. This indicated that there is a significant emergence in lean–green supply chain management field which was also evident in the extensive reviews done by Martínez-Jurado and Moyano-Fuentes (2014) and Mollenkopf, et al. (2010).

Out of the validated conceptual models analysed Aguado, Alvarez, and Domingo (2013) proposed a model to harmonise efficiency and sustainable improvement in a lean production system based on environmental innovation. The pull methodology and extended value stream mapping were instrumental in implementing this model. However limited availability of data bases to acquire information is a constraint in application of this model. This model can be further improved by amalgamating sustainable business archetypes suggested by Bocken, Short, Rana, and Evans (2014) which are maximise material and energy efficiency, create value from waste, and substitute with renewable and natural processes under technological innovation.

Pampanelli, et al. (2014) presented a model which amalgamates lean and green thinking to be applied for manufacturing at a cell level which aims to decrease waste during production and minimise negative effects on the environment. But the proposed model is constrained to a cell level in manufacturing context. Since this model is applied for a cell level, the applicability for plant level could be incorporated; this could even be expanded for upstream and downstream supply chains. Ng, et al. (2015) presented a method which integrate and implement lean and green practices which was consistent with previous work of Brown, et al. (2014),Faulkner and Badurdeen (2014), Kurdve, Zackrisson, Wiktorsson, and Harlin (2014) and Marimin, et al. (2014). As Brown, et al. (2014) suggested to narrow the scope of metrics by having focus on a narrow area which could be widely applicable Ng, et al. (2015) proposed a carbon-value efficiency (CVE) which could be used as a standardization tool to assess the amount of value added time produced per unit of carbon footprint. There is limited generalizability in this application was specific metal stamp production context. This could be further improved by applying for multiple case studies from different industries. This model could be further integrated with sustainability approaches such as zero emissions initiatives and low carbon manufacturing solutions. Lean and sustainability were further modelled by Yang, et al. (2011) showing lean manufacturing as vital precursor of environmental sustainability practice and Piercy and Rich (2015) a stage-based theoretical model of lean-sustainability. Future research can be carried out on developing scales and calibration tools for multiple dimensions of environmental sustainability. Also further applied for different industries and even for supply chain can be considered. The compatibility of life cycle assessment with the lean and green model would be prospective future research. Carvalho, Duarte, and Cruz Machado (2011) conceptualised a model to

identify the synergistic effects, divergences caused by lean, agile, resilience and green paradigm. This study was constrained to principle paths between KPIs (key performance indicators) and supply chain features. Agility is a critical ability for many organizations to quickly adapt and thrive forward in a changing business environment. Therefore integration of this concept for lean and green could open opportunistic pathways to thrive forward in the competitive business industry. Wu, et al. (2015) suggested an integrated sustainable practice model; considering prevalent lean green and social practices. The framework proposed that the integration of practices will affect the triple bottom line than individually implementing the activities. In addition this model could further improve the social practice aspect by using concepts as "consumer care" as there is an increasing trend on being conscious on consumer wellbeing. This model was validated using a case study in auto fashion industry in China and hence there is limited generalizability. A larger sample of multiple case studies could be used to further validate this model.

Out of these validated conceptual models some authors used mathematical modelling, simulation and optimisation. For example Diaz-Elsayed, Jondral, Greinacher, Dornfeld, and Lanza (2013) proposed an approach which required creating a discrete event simulation model. This model could be developed further by adding quantitative and qualitative environmental management practices within the industries such as lighting levels, air condition, compressed air (e.g.: actual heat load, AC efficiency), electrical systems (e.g.: power factor, load scheduling), boilers (e.g.: capacity) etc. and identify quantifiable costs and benefits related to these green strategies. This method could be also used as an internal calibration tool for the organization to assess and benchmark environmental performance along with operational performance. Sawhney, et al. (2007) presented the En-Lean method to facilitating the developing association of lean practices and environmental considerations for a specific process by using HTML and JavaScript codes. Miller, et al. (2010) also proposed a model which leads the analysts to investigate manufacturing process by using mathematical optimization in choosing the suppliers which resulted major financials savings in terms of transportation and partnering fewer suppliers to one step. Fahimnia, Sarkis, and Eshragh (2015) suggested a tactical supply chain planning model (complex mathematical model and solution approach) to assess the trade-offs among cost and deterioration of the environment by means of carbon gas emissions, energy usage and waste production. For wider application of these models these could be tested in different industries considering similarity in environmental impacts. However in using mathematical model, simulation and optimisation; the requirement of data and the complex nature of the model may be challenging for certain organizational contexts. The factors of the volatile external environment such as government regulations, polices and competitions by other companies in the industry can be incorporated to improve these models.

In discussing the role of supply chain Duarte, Cabrita, and Machado (2011) proposed a conceptual model combining lean and green supply chain into a performance measurement system, utilising the balanced scorecard method. Hajmohammad, Vachon, Klassen, and Gavronski (2013) also posited a model that shows supply chain management encourage and lean practices are positively influencing environmental performance. Integrating the concept of "sustainable sourcing" for the lean supply chain management could pave the way for better performance in lean and green supply chain management.

For successful implementation of sustainable business practice; green leadership (top management support for sustainability), strategic green management (greener vision, environmental policy); people engagement, inculcation of sustainability culture, environmental management systems with continuous improvement, environmental auditing, environmental foot printing (carbon, ecological, water etc.) are key drivers. This criticality is evident in the study conducted by (Duarte and Cruz-Machado (2013)) investigating different business models represented in awards, standards and frameworks which are capable of contributing to modelling a lean and green approach for an organization and its supply chain. The findings revealed that majority of models considered supply chain, need for leadership, strategic planning, people, processes, stakeholders and results as important elements for change in culture and continuous improvement in organizations. Lean practices could be aligned with sustainability to optimise material efficiency, energy efficiency, water efficiency (e.g.: green manufacturing) and to shift from conventional processes to renewable energy options and biomimicry design processes. For this purpose lean and green frameworks can be combined integrated with environmental management practices such as environmental management systems, environmental policy, environmental auditing, life cycle analysis, green manufacturing, zero emission initiatives, biomimicry, cradle to cradle etc. These constructs provide a good breeding ground for a number of future researches which could be beneficial in both academic and industrial arena.

## 5 Conclusions

Sustainable business practice is influenced by numerous elements such as environmental management systems, policies, auditing, life cycle assessment, reporting, legal litigations and risks, triple bottom line etc. Lean thinking is viewed as an underutilised pathway which could be used to yield better results from integrating with environmental sustainability. As the global cleaner production and sustainable consumption conference is celebrating two decades of journal publications this review is aimed to analyse research publications over the last twenty years and discuss implications for probable future. This discussion was twofold; comprising potential lean practices that are much readily available for industrialists, and targeted interventions to transfer lean thinking as solutions in the future. These interventions intent to harness the best outcomes by integrating lean thinking to sustainable concepts such as resource productivity and whole system approach.

From a resource efficiency perspective lean thinking is a critical approach, but still underutilised within the modern industrial system. Lean practices were commonly found in manufacturing sector, especially automobile and was emerging in construction, metal, food and other sectors. The review analysed specific lean tools which could be utilised to reduce specific environmental impact and models integrating lean and green. The review presents a number of *lean and lean integrated* tools and practices such as value stream mapping, total productive maintenance, employee engagement, Kaizen, 5S, inventory reduction etc. addressing green waste, energy and emissions but there is a lack of lean practices to support chemical and water management. Therefore academics and practitioners could study lean tools or lean integrated practices to incorporate with chemical and water management. In considering the green and lean models there were various conceptual and validated conceptual models which were mostly applied for a specific industry or a context. This establishes a gap of knowledge in a system for being able to consider different categories of environmental impacts in different industries and choose best lean tools or models for that problem in a way to ensure holistic exploration (i.e.: spanning all environmental issues not just waste and energy streams). This will be helpful for linking them with specific lean tools to a larger scope of environmental issues and reduce the magnitude of the impact. Future research should be carried out to develop a system to fulfil above gap and to determine the compatibility of lean practices with sustainability concepts such as low carbon manufacturing, green chemistry, biomimicry, industrial ecology and regenerative design. This way we could further explore the synergistic effect of above elements on lean and green business process management.

More attention should be paid to understanding the gaps highlighted above and delve more deeply into, how this integration of lean and green paradigm should be executed as a pathway for corporate sustainable development. Structuring, categorising and finding relationship between sustainable work streams and lean practices can stimulate academics to conduct further research on simultaneous implementation of lean and sustainable business practices and their compatibility. In addition industrialists can view more opportunities in lean thinking not only towards excellence in manufacturing but also fulfilling their responsibility towards the environment as a collective effort. This paper will be for the benefit of both researchers and industrialists in gaining valuable information on the influence of lean practices in increasing corporate environmental sustainability. And thereby it will explore new paradigms and pathways to achieve a balance in environmental and economic priorities in sustainable business practice.

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**References**

Aguado, S., Alvarez, R., & Domingo, R. (2013). Model of efficient and sustainable improvements in a lean production system through processes of environmental innovation. *Journal of Cleaner Production, 47*(0), 141-148. doi:http://dx.doi.org/10.1016/j.jclepro.2012.11.048

Amani, P., Lindbom, I., Sundström, B., & Östergren, K. (2015). Green-Lean Synergy-Root-Cause Analysis in Food Waste Prevention. *International Journal on Food System Dynamics, 6*(2), 99-109. Retrieved from http://centmapress.ilb.uni-bonn.de/ojs/index.php/fsd/article/viewFile/487/490.

Azevedo, S. G., Carvalho, H., Duarte, S., & Cruz-Machado, V. (2012). Influence of green and lean upstream supply chain management practices on business sustainability. *Engineering Management, IEEE Transactions on, 59*(4), 753-765. doi:10.1109/TEM.2012.2189108

Ball, P. (2015). Low energy production impact on lean flow. *Journal of Manufacturing Technology Management, 26*(3), 412. Retrieved from ABI/INFORM Complete. doi:10.1108/JMTM-12-2012-0120

Banawi, A., & Bilec, M. M. (2014). A framework to improve construction processes: Integrating Lean, Green and Six Sigma. *International Journal of Construction Management, 14*(1), 45-55. doi:http://dx.doi.org/10.1080/15623599.2013.875266

Bandehnezhad, M., Zailani, S., & Fernando, Y. (2012). An empirical study on the contribution of lean practices to environmental performance of the manufacturing firms in northern region of Malaysia. *International Journal of Value Chain Management, 6*(2), 144-168. doi:10.1504/IJVCM.2012.048379

Bazeley, P., & Jackson, K. (2013). *Qualitative data analysis with NVivo*: Sage Publications Limited.

Bergmiller, G. G., & McCright, P. R. (2009). Parallel models for lean and green operations. In *Proceedings of the 2009 Industrial Engineering Research Conference, Miami, FL*.

Bergmiller, G. G. P., & McCright, P. R. P. (2011). Achieving Total Sustainability by Cleaning Up the Dirty Dozen. *IIE Annual Conference. Proceedings*, 1-8. Retrieved from ABI/INFORM Complete.Retrieved from http://search.proquest.com/docview/1190602861?pq-origsite=gscholar.

Bocken, N. M. P., Short, S. W., Rana, P., & Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production, 65*(0), 42-56. doi:http://dx.doi.org/10.1016/j.jclepro.2013.11.039

Briner, R. B., & Denyer, D. (2012). Systematic review and evidence synthesis as a practice and scholarship tool. *Handbook of evidence-based management: Companies, classrooms and research*, 112-129. Retrieved from http://www.cebma.info/wp-content/uploads/Briner-Denyer-Systematic-Review-Evidence-Synthesis.pdf.

Brown, A., Amundson, J., & Badurdeen, F. (2014). Sustainable value stream mapping (Sus-VSM) in different manufacturing system configurations: application case studies. *Journal of Cleaner Production, 85*(0), 164-179. doi:http://dx.doi.org/10.1016/j.jclepro.2014.05.101

Byers, W., Lindgren, G., Noling, C., & Peters, D. (2010). Water Reclamation Strategies and Technologies. In *Industrial Water Management* (pp. 3-1-3-27): John Wiley & Sons, Inc.

Carvalho, H., Duarte, S., & Cruz Machado, V. (2011). Lean, agile, resilient and green: divergencies and synergies. *International Journal of Lean Six Sigma, 2*(2), 151-179. doi:10.1108/20401461111135037

Chaplin, L., & Simon, T. J. O. R. (2014). Lean Six Sigma and marketing: a missed opportunity. *International Journal of Productivity and Performance Management, 63*(5), 665-674. Retrieved from ABI/INFORM Complete. doi:10.1108/IJPPM-09-2013-0155

Chiarini, A. (2014). Sustainable manufacturing-greening processes using specific Lean Production tools: an empirical observation from European motorcycle component manufacturers. *Journal of Cleaner Production, 85*(0), 226-233. doi:http://dx.doi.org/10.1016/j.jclepro.2014.07.080

Cosimato, S., & Troisi, O. (2015). Green supply chain management. *TQM Journal, 27*(2), 256-276. Retrieved from ABI/INFORM Complete. doi:10.1108/TQM-01-2015-0007

D'Errico, F., Perricone, G., & Oppio, R. (2009). A New Integrated Lean Manufacturing Model for Magnesium Products. *JOM, 61*(4), 14-18. Retrieved from ABI/INFORM Complete.Retrieved from http://search.proquest.com.ezp01.library.qut.edu.au/abicomplete/docview/232560842/839C66D2335E4D4APQ/1?accountid=13380.

Dhingra, R., Kress, R., & Upreti, G. (2014). Does lean mean green? *Journal of Cleaner Production, 85*(0), 1-7. doi:http://dx.doi.org/10.1016/j.jclepro.2014.10.032

Diaz-Elsayed, N., Jondral, A., Greinacher, S., Dornfeld, D., & Lanza, G. (2013). Assessment of lean and green strategies by simulation of manufacturing systems in discrete production environments. *CIRP Annals - Manufacturing Technology, 62*(1), 475-478. doi:http://dx.doi.org/10.1016/j.cirp.2013.03.066

Duarte, S., Cabrita, R., & Machado, V. C. (2011). Exploring lean and green supply chain performance using balanced scorecard perspective. In *Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management* (pp. 520-525).

Duarte, S., & Cruz-Machado, V. (2013). Modelling lean and green: a review from business models. *International Journal of Lean Six Sigma, 4*(3), 228-250. doi:10.1108/IJLSS-05-2013-0030

Dües, C. M., Tan, K. H., & Lim, M. (2013). Green as the new Lean: how to use Lean practices as a catalyst to greening your supply chain. *Journal of Cleaner Production, 40*(0), 93-100. doi:http://dx.doi.org/10.1016/j.jclepro.2011.12.023

Easterby-Smith, M., Thorpe, R., & Jackson, P. R. (2012). *Management research*: Sage.

Esfandyari, A., Härter, S., Javied, T., & Franke, J. (2015). A Lean Based Overview on Sustainability of Printed Circuit Board Production Assembly. *Procedia CIRP, 26*, 305-310. doi:http://dx.doi.org/10.1016/j.procir.2014.07.059

Fahimnia, B., Sarkis, J., & Eshragh, A. (2015). A tradeoff model for green supply chain planning:A leanness-versus-greenness analysis. *Omega, 54*, 173-190. doi:http://dx.doi.org/10.1016/j.omega.2015.01.014

Faulkner, W., & Badurdeen, F. (2014). Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance. *Journal of Cleaner Production, 85*, 8-18. doi:10.1016/j.jclepro.2014.05.042

Fliedner, G. (2008). Sustainability: a new lean principle. In *Proceedings of the 39th annual meeting of the decision sciences institute, Baltimore, Maryland* (pp. 3321-3326).

Florida, R. (1996a). Lean and green: The move to environmentally conscious manufacturing. *California Management Review, 39*(1), 80-105. Retrieved from ProQuest Central.Retrieved from http://search.proquest.com.ezp01.library.qut.edu.au/abicomplete/docview/216129819/AC58270D9642C1PQ/1?accountid=13380.

Florida, R. L. (1996b). *Lean and green: the move to environmentally conscious manufacturing*: California Management Review.

Folinas, D., Aidonis, D., Malindretos, G., Voulgarakis, N., & Triantafillou, D. (2014). Greening the agrifood supply chain with lean thinking practices. *International Journal of Agricultural Resources, Governance and Ecology 6, 10*(2), 129-145. doi:10.1504/IJARGE.2014.063580

Folinas, D., Aidonis, D., Triantafillou, D., & Malindretos, G. (2013). Exploring the greening of the food supply chain with lean thinking techniques. *Procedia Technology, 8*, 416-424. doi:10.1016/j.protcy.2013.11.054

Galeazzo, A., Furlan, A., & Vinelli, A. (2014). Lean and green in action: interdependencies and performance of pollution prevention projects. *Journal of Cleaner Production, 85*(0), 191-200. doi:http://dx.doi.org/10.1016/j.jclepro.2013.10.015

Garza-Reyes, J. A. (2015). Lean and green – a systematic review of the state of the art literature. *Journal of Cleaner Production, 102*, 18-29. doi:http://dx.doi.org/10.1016/j.jclepro.2015.04.064

Gibson, I., Yoke San, W., Pham, D., Pham, P., & Thomas, A. (2008). Integrated production machines and systems-beyond lean manufacturing. *Journal of Manufacturing Technology Management, 19*(6), 695-711. doi:10.1108/17410380810888094

González-Benito, J., & González-Benito, Ó. (2008). Operations management practices linked to the adoption of ISO 14001: An empirical analysis of Spanish manufacturers. *International Journal of Production Economics, 113*(1), 60-73.

Govindan, K., Kannan, D., & Shankar, M. (2014). Evaluation of green manufacturing practices using a hybrid MCDM model combining DANP with PROMETHEE. *International Journal of Production Research*(ahead-of-print), 1-28. doi:10.1080/00207543.2014.898865

Hajmohammad, S., Vachon, S., Klassen, R. D., & Gavronski, I. (2013). Lean management and supply management: their role in green practices and performance. *Journal of Cleaner Production, 39*(0), 312-320. doi:http://dx.doi.org/10.1016/j.jclepro.2012.07.028

Hillary, R. (2000). *Small and medium-sized enterprises and the environment: business imperatives*: Greenleaf Publishing.

Hong, P., Ga Yang, M., & D. Dobrzykowski, D. (2014). Strategic customer service orientation, lean manufacturing practices and performance outcomes. *Journal of Service Management, 25*(5), 699. Retrieved from ABI/INFORM Complete. doi:10.1108/JOSM-12-2013-0355

IEA. (2007). *Tracking industrial energy efficiency and CO2 emissions: in support of the G8 plan of action : energy indicators*. FR: International Energy Agency.

Jovane, F., Yoshikawa, H., Alting, L., Boër, C., Westkamper, E., Williams, D., . . . Paci, A. (2008). The incoming global technological and industrial revolution towards competitive sustainable manufacturing. *CIRP Annals-Manufacturing Technology, 57*(2), 641-659. doi:10.1016/j.cirp.2008.09.010

King, A. A., & Lenox, M. J. (2001). Lean and green? An empirical examination of the relationship between lean production and environmental performance. *Production and Operations Management, 10*(3), 244-256. Retrieved from Scopus. doi:1059-1478/01/l 003/244$1.25

Kurdve, M., Shahbazi, S., Wendin, M., Bengtsson, C., & Wiktorsson, M. (2015). Waste flow mapping to improve sustainability of waste management: a case study approach. *Journal of Cleaner Production, 98*, 304-315. doi:http://dx.doi.org/10.1016/j.jclepro.2014.06.076

Kurdve, M., Zackrisson, M., Wiktorsson, M., & Harlin, U. (2014). Lean and green integration into production system models – experiences from Swedish industry. *Journal of Cleaner Production, 85*(0), 180-190. doi:http://dx.doi.org/10.1016/j.jclepro.2014.04.013

Levy, Y., & Ellis, T. J. (2006). A systems approach to conduct an effective literature review in support of information systems research. *Informing Science: International Journal of an Emerging Transdiscipline, 9*(1), 181-212. Retrieved from http://www.scs.ryerson.ca/aferworn/courses/CP8101/CLASSES/ConductingLiteratureReview.pdf.

Macagno, T. (2013). A Model for Managing Corporate Sustainability. [Article]. *Business & Society Review (00453609), 118*(2), 223-252. Retrieved from bsh. doi:10.1111/basr.12009

Marimin, Darmawan, M. A., Machfud, Islam Fajar Putra, M. P., & Wiguna, B. (2014). Value chain analysis for green productivity improvement in the natural rubber supply chain: a case study. *Journal of Cleaner Production, 85*, 201-211. doi:http://dx.doi.org/10.1016/j.jclepro.2014.01.098

Martínez-Jurado, P. J., & Moyano-Fuentes, J. (2014). Lean Management, Supply Chain Management and Sustainability: A Literature Review. *Journal of Cleaner Production, 85*(0), 134-150. doi:http://dx.doi.org/10.1016/j.jclepro.2013.09.042

Maxwell, J., Briscoe, F., Schenk, B., & Rothenberg, S. (1998). Case study: Honda of America Manufacturing, Inc.: Can lean production practices increase environmental performance? *Environmental Quality Management, 8*(1), 53-61. doi:1088-1 91 3/98/0801 053-09

Miller, G., Pawloski, J., & Standridge, C. R. (2010). A case study of lean, sustainable manufacturing. *Journal of industrial engineering and management, 3*(1), 11-32. doi:10.3926/jiem.2010.v3n1.p11-32

Mollenkopf, D., Stolze, H., Tate, W. L., & Ueltschy, M. (2010). Green, lean, and global supply chains. *International Journal of Physical Distribution & Logistics Management, 40*(1-2), 14-41. doi:10.1108/09600031011018028

Moscardo, G. (2013). *Sustainability in Australian business: principles and practice*. Milton, Qld: John Wiley and Sons Australia.

Moser, T. (2001). MNCs and Sustainable Business Practice: The Case of the Colombian and Peruvian Petroleum Industries. *World Development, 29*(2), 291-309. doi:http://dx.doi.org/10.1016/S0305-750X(00)00094-2

Moyano-Fuentes, J., Sacristán-Díaz, M., & Martínez-Jurado, P. J. (2012). Cooperation in the supply chain and lean production adoption. *International Journal of Operations & Production Management, 32*(9), 1075-1096. Retrieved from ABI/INFORM Complete. doi:http://dx.doi.org/10.1108/01443571211265701

Ng, R., Low, J. S. C., & Song, B. (2015). Integrating and implementing Lean and Green practices based on proposition of Carbon-Value Efficiency metric. *Journal of Cleaner Production, 95*, 242-255. doi:10.1016/j.jclepro.2015.02.043

Ogunbiyi, O., Adebayo, O., & Goulding, J. (2014). An empirical study of the impact of lean construction techniques on sustainable construction in the UK. *Construction Innovation, 14*(1), 88-107. Retrieved from ABI/INFORM Complete. doi:http://dx.doi.org/10.1108/CI-08-2012-0045

Okoli, C., & Schabram, K. (2010). A guide to conducting a systematic literature review of information systems research. *Available at SSRN 1954824*. Retrieved from http://sprouts.aisnet.org/10-26.

Ōno, T. (1988). *Toyota production system: beyond large-scale production*: Productivity press.

Pampanelli, A. B., Found, P., & Bernardes, A. M. (2014). A Lean & Green Model for a production cell. *Journal of Cleaner Production, 85*(0), 19-30. doi:http://dx.doi.org/10.1016/j.jclepro.2013.06.014

Piercy, N., & Rich, N. (2015). The relationship between lean operations and sustainable operations. *International Journal of Operations & Production Management, 35*(2), 282. Retrieved from ABI/INFORM Complete. doi:10.1108/IJOPM-03-2014-0143

Quaddus, M. A., & Siddique, M. A. B. (2011). *Handbook of corporate sustainability: frameworks, strategies and tools*. Northhampton, MA; Cheltenham, UK: Edward Elgar Pub.

Rothenberg, S., Pil, F. K., & Maxwell, J. (2001). Lean, green, and the quest for superior environmental performance. *Production and Operations Management, 10*(3), 228-243. Retrieved from Scopus. doi:1059-1478/01/1003/228$1.25

Saunders, M., Lewis, P., & Thornhill, A. (2012). *Research methods for business students* (Vol. 6th). New York; Harlow, England: Pearson.

Sawhney, R., Teparakul, P., Bagchi, A., & Li, X. (2007). En-Lean: a framework to align lean and green manufacturing in the metal cutting supply chain. *International Journal of Enterprise Network Management, 1*(3), 238-260. Retrieved from http://www.inderscienceonline.com/doi/pdf/10.1504/IJENM.2007.012757.

Schaper, M. (2002). The challenge of environmental responsibility and sustainable development: Implications for SME and entrepreneurship academics. *Radical changes in the world: Will SMEs soar or crash*, 541-553.

Serageldin, I. (1996). Sustainability as opportunity and the problem of social capital. *Brown J. World Aff., 3*, 187.

Seuring, S., Müller, M., Westhaus, M., & Morana, R. (2005). Conducting a literature review-the example of sustainability in supply chains. *Research methodologies in supply chain management*, 91-106. doi:10.1007/3-7908-1636-1_7

Simons, D., & Mason, R. (2003). Lean and green: doing more with less. *ECR Journal, 3*(1), 84-91. Retrieved from http://ecr-all.org/files/lean-and-green-doing-more-with-less.pdf.

Simpson, D. F., & Power, D. J. (2005b). Use the supply relationship to develop lean and green suppliers. *Supply Chain Management: An International Journal, 10*(1), 60-68. doi:10.1108/13598540510578388

Smith, M. H., Hargroves, K., & Desha, C. (2010). *Cents and Sustainability: Securing our common future by decoupling economic growth from environmental pressures*: Earthscan.

Sobral, M. C., Sousa Jabbour, A. B. L. d., & Chiappetta Jabbour, C. J. (2013). Green Benefits From Adopting Lean Manufacturing: A Case Study From the Automotive Sector. [Article]. *Environmental Quality Management, 22*(3), 65-72. Retrieved from bsh. doi:10.1002/tqem.21336

Soltero, C., & Waldrip, G. (2002). Using Kaizen to Reduce Waste and Prevent Pollution. *Environmental Quality Management, 11*(3), 23-38. doi:10.1002/tqem.10026

Vais, A., Miron, V., Pedersen, M., & Folke, J. (2006). "Lean and Green" at a Romanian secondary tissue paper and board mill - Putting theory into practice. *Resources, Conservation and Recycling, 46*(1), 44-74. Retrieved from Scopus. doi:10.1016/j.resconrec.2005.06.005

Venkat, K., & Wakeland, W. (2006). Is lean necessarily green? In *Proceedings of the 50th Annual Meeting of the ISSS-2006, Sonoma, CA, USA*.

Verrier, B., Rose, B., Caillaud, E., & Remita, H. (2014). Combining organizational performance with sustainable development issues: the Lean and Green project benchmarking repository. *Journal of Cleaner Production, 85*, 83-93. doi:10.1016/j.jclepro.2013.12.023

Vinodh, S., Arvind, K. R., & Somanaathan, M. (2011). Tools and techniques for enabling sustainability through lean initiatives. *Clean Technologies and Environmental Policy, 13*(3), 469-479. Retrieved from ABI/INFORM Complete. doi:http://dx.doi.org/10.1007/s10098-010-0329-x

Von Weizsacker, E. U., Hargroves, C., Smith, M. H., Desha, C., & Stasinopoulos, P. (2009). *Factor Five : Transforming the Global Economy through 80% Improvements in Resource Productivity*. Hoboken: Routledge.

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *Management Information Systems Quarterly, 26*(2), 3. Retrieved from http://intranet.business-science-institute.com/pluginfile.php/247/course/summary/Webster%20%20Watson.pdf.

Welford, R. (1996). *Corporate environmental management: systems and strategies*. London: Earthscan.

White, G. R. T., & James, P. (2014). Extension of process mapping to identify “green waste”. [Article]. *Benchmarking, 21*(5), 835-850. Retrieved from bsh. doi:10.1108/BIJ-07-2012-0047

Wiengarten, F., Fynes, B., & Onofrei, G. (2013). Exploring synergetic effects between investments in environmental and quality/lean practices in supply chains. *Supply Chain Management, 18*(2), 148-160. Retrieved from ABI/INFORM Complete. doi:http://dx.doi.org/10.1108/13598541311318791

Womack, J. P., Jones, D. T., & Roos, D. (1990). *Machine that changed the world*: Simon and Schuster.

Wu, L., Subramanian, N., Abdulrahman, M. D., Liu, C., Lai, K. H., & Pawar, K. S. (2015). The Impact of Integrated Practices of Lean, Green, and Social Management Systems on Firm Sustainability Performance-Evidence from Chinese Fashion Auto-Parts Suppliers. *Sustainability, 7*(4), 3838-3858. doi:10.3390/su7043838

Wu, P., Low, S. P., & Jin, X. (2013). Identification of non-value adding (NVA) activities in precast concrete installation sites to achieve low-carbon installation. *Resources, Conservation and Recycling, 81*, 60-70. Retrieved from Scopus. doi:10.1016/j.resconrec.2013.09.013

Yang, M. G., Hong, P., & Modi, S. B. (2011). Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. *International Journal of Production Economics, 129*(2), 251-261. doi:http://dx.doi.org/10.1016/j.ijpe.2010.10.017