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The relationship between lean operations and sustainable operations

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Abstract

Purpose – The adoption of lean operational practices and independently the uptake of business practices related to sustainability and corporate social responsibility continues to grow. Past research has hinted at relationships between these two areas – suggesting that "lean is green" (e.g. Florida, 1996). The lean mantra of waste reduction and "doing more with less" is immediately apparent as delivering environmental benefits and has formed the basis of past research (e.g. Hughes, 2012). Almost all research linking lean operations or lean supply chains to sustainability issues have focused exclusively on environmental impact. The purpose of this paper is to explore the broader sustainability benefits of lean operations.

Design/methodology/approach – The paper uses a longitudinal multi-year (up to four years observation), multi-case analysis ($n = 5$).

Findings – The paper reports that lean operations meet a wide range of sustainability outcomes beyond environmental benefits (including supply monitoring, transparency, workforce treatment, and community engagement). The paper specifies the internal and external policies, procedures, tools, and strategies for implementation of lean and sustainable operations management (OM). This is encapsulated in the development of a stage-based theoretical model of lean-sustainability. Further, it is proposed that lean implementation and sustainability performance are in fact interlinked.

Originality/value – Past research on the role of lean operations in improving sustainably has focused almost exclusively on environmental benefits accruing from toolkit/workplace level waste reduction. This paper demonstrates that lean provides more than a toolkit (a philosophy and strategic direction) and that this meets a wide range of sustainable outcomes. This finding makes major contributions to conceptualising how lean operations influence sustainability outcomes. The paper develops the first integrative stage-based model of lean and sustainable OM.

Keywords Sustainability, Operations management, Lean, Green, Case study

Paper type Research paper

Introduction

How to fully integrate sustainability issues with lean operations and supply chains has been identified as one of the major challenges facing contemporary operations management (OM) (Kleindorfer *et al.*, 2005). The mutually beneficial relationship between sustainability and economic performance is now generally accepted as true (Porter, 1991; Porter and van der Linde, 1995; Jeffers, 2010). Previous studies highlight a range of positive relationships between sustainability and economic performance, including: cost savings, product quality improvement, increasing market share, getting ahead of legislation, accessing new markets, increasing employee retention, and improving public relations (Zhu and Sarkis, 2004).

It is also clear that OM plays an important part in delivering these positive outcomes, although what that role may be is less certain: "We are just beginning to understand and map the territory for sustainable OM" (Kleindorfer *et al.*, 2005, p. 489). While Florida's (1996) study of nearly 2,000 companies highlighted a strong positive relationship between the outcome of good operations and the environment, the nature

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of achieving this outcome (i.e. the process of strategy formation and implementation) between sustainability and OM is unclear and the engagement with "lean operations" remains under-examined. Addressing this topic 16 years later Azevedo *et al.* (2012) report that there remain almost no rigorous academic studies investigating lean operations and sustainability.

A focus on lean operations as a specific subset of world-class operational practices is a recurrent theme in the operations literature (e.g. Piercy and Rich, 2009). Researchers are beginning to link lean operations to sustainability, promoting the mantra that "lean is green" (e.g. Corbett and Klassen, 2006). One of the goals of lean operations is to use fewer resources to generate the same outcome. This is clearly, inherently environmentally friendly: as less materials are used in production, and also quality improvements reduce rework, scrap, power/water consumption, and pollution costs , environmental benefits are observed (King and Lenox, 2001; Rothenberg *et al.*, 2001; Simpson and Power, 2005). This conceptualisation has formed the basis of almost all past research on lean operations and sustainability. Thus, the sustainability benefits lean operations can affect have been limited to environmental performance (e.g. Florida, 1996; Zhu and Sarkis, 2004; Kainuma and Tawara, 2006; Lapinski *et al.*, 2006; Farish, 2009; Mollenkopf *et al.*, 2010; Oglethorpe and Heron, 2010; Cabral *et al.*, 2012; Miller and Sardner, 2012; Prasad and Sutharasan, 2012).

These environmental benefits have been seen as a by-product of lean operational improvement (Florida, 1996), what Corbett and Klassen (2006) term "the law of unexpected side benefits". In this paper we do not question this past research. However, we contend that the benefits of lean are more extensive, including strategic direction with explicit (expected) outcomes, and strategic and operational improvements that cover a broader range of sustainability issues than just the environment. Past studies have hinted that such benefits may be possible but also identify that fully conceptualising this process and harvesting the benefits is complex (e.g. King and Lenox, 2001; Rothenberg *et al.*, 2001).

One major issue to contend with in this process is to properly define lean operations (Hines *et al.*, 2004). Many sustainability studies have taken a limited view of lean as merely an operational level waste reduction toolkit (e.g. Lapinski *et al.*, 2006; Green *et al.*, 2010; Cabral *et al.*, 2012; Miller and Sarder, 2012) or studied it as only just-in-time or quality management (e.g. Zhu and Sarkis, 2004). These misconceptions are perhaps unsurprising given the same issues occur in the general OM literature (e.g. Slack, 1991). However, several publications on lean operations suggest a strategic as well as operational approach (e.g. Akao, 1989; Womack *et al.*, 1990; Hines *et al.*, 2004).

This research resolves several issues: fully defining lean operations, identifying a broad range of sustainability outcomes (beyond the environment), and linking these sustainability outcomes back to lean operations. A longitudinal, in-depth multi-case analysis is performed to address one research question: how do lean operations generate positive performance across multiple dimensions of corporate social responsibility?

Lean improvement

Past studies of lean have predominantly focused on two conceptualisations: those that seek to define lean based on the five principles (value, value stream, flow, pull, perfection) defined by Womack and Jones (1996) (for instance, Piercy and Rich, 2009); and, those that have selected a range of lean activities to form their own "house of lean" (for instance, Bicheno and Catherwood, 2005). Both of these approaches have merit in

demonstrating the basis of lean change and often are based on evaluations of past lean implementation so are dictated by the companies of study. In attempting to define a complete conceptualisation of lean in its purest sense, it is necessary to demonstrate the full range of lean activities combined. In doing so, it is possible to identify two levels of lean operations: those at the workplace (centred around operational improvements); and, those at the strategic operating level (focused on the strategy process and broader organising philosophy of the company).

(i) The workplace level

Research agrees that all lean implementation changes the activities on the shop-floor. Many studies have focused on visual elements of lean operations (for instance 5-S cleanup activities (e.g. Cooke *et al.*, 2010)). The broader changes in workforce treatment are a result of larger strategic organisational changes in the company. The specific activities provide a small improvement in operational efficiency but are primarily important for engaging the workforce in change – to increase their motivation for the larger changes required (Grief, 1991). Building on a foundation of good worker relations, three key areas of lean improvement are identifiable:

- total quality management – tools and approaches, such as statistical process control, brainstorming, quality detection, all focused on improving quality of materials and production processes (see Ishikawa, 1985);
- total preventative maintenance (TPM) – activities related to ensuring machine reliability and hence production quality dependability and speed (see McCarthy and Rich, 2004); and
- flow production system – activities focused on changing the way in which products and materials are handled, and the move toward buffer/stock reduction (see Ohno, 1988; MacDuffie, 1995).

(ii) The strategic level

At the strategic level a full lean implementation requires several changes. The strategy process itself is moved away from the traditional management-by-objectives approach to focus on policy deployment that "challenges" lower levels of the organisation to meet strategic goals (Akao, 1989). In parallel several philosophical/organising logic changes take place moving from a focus on management of functions (hierarchy) to cross-functional processes (Kurogane, 1993); this extends not just to the internal operation of the company but to external supply partners, with a move toward co-operative, integrative relationships rather than market-based purchasing (Lamming, 1993). This is all underpinned by a shift in the way workers are perceived in the organisation – from seeing them as costs of production to value-adding resources, that should be better trained, treated, and paid so as to engage them with continuous improvement in the workplace (MacDuffie, 1995).

While ad-hoc application of any one of these approaches can lead to some improvement, only when all of these elements are strategic and workplace issues are aligned and implemented together are major gains – in product quality, and cost reduction through waste reduction and productivity – realised (Rich *et al.*, 2006). While some studies hint at strategic changes (usually only focused on supply integration), most focus solely on the workplace tools without attesting to the strategic changes that facilitate them. Past studies of lean have suffered from omission or misinterpretation of

many of the aspects identified here. Supply chain interaction is the only element of the strategic changes that take place which commonly occurs in the literature (e.g. Lamming, 1993; Moyano-Fuentes *et al.*, 2012); the remainder of the changes are largely ignored with most studies focusing purely on the workplace or tool level (e.g. Osada, 1991; Hirando, 1995; George *et al.*, 2003; Wan and Chen, 2008; Green *et al.*, 2010). Even those focused on tools, often do not implement them in a systematic manner (e.g. Clargo, 2002). Many ignore TPM altogether (e.g. Pascale and Athos, 1981; Merli, 1990; Schroeder and Flynn, 2001), focus only on quality (e.g. Oakland, 1989), or focus on JIT purely as stock reduction, without understanding internal TQM and TPM changes needed (e.g. Sandras, 1989; Slack, 1991). Thus, when considering lean operations and sustainability, it is unsurprising that many studies have seen lean as purely a workplace waste reduction (environmental) approach – this misconception is apparent in (too) much of the general OM literature.

Lean and green operations

Early research suggested that a win-win scenario existed with environmental and economic performance (see: Porter, 1991; Porter and van der Linde, 1995). Subsequent studies have sought to investigate in more detail the reason for this causation and the role of OM. Florida (1996) suggested that environmental and industrial/economic performance improvement are interlinked as both stem from a common drive: "Firms that are innovative in terms of their manufacturing process are likely to be more imaginative in addressing environmental costs and risks" (Florida, 1996, p. 80). At the core of Florida's argument is that innovation drives operational and organisational strategy and that innovation will lead to both operational and environmental improvement in tandem. This is supported by several studies that have found a two-way relationship between operational and environmental performance – that a focus on one is often present when there is a focus on the other (Pil and Rothenberg, 2003; Kleindorfer *et al.*, 2005): "The practices that support lean manufacturing are similar to the practices that support environmental performance" (Simpson and Power, 2005, p. 63). There is ample evidence in the research literature of a focus on lean operations improving the environment or a focus on the environment leading to operational/lean improvement (see Tables I and II).

Just one example of this is in new product development; one important outcome of innovation and/or lean operations is increased new product development (Florida, 1996). With new generation of products, the firm has the opportunity to redesign layout, facilities, engage new suppliers, work with new materials, and address closed-loop issues at the design stage (Farish, 2009). The generational shift provides a greater opportunity for environmental improvement than retro-fitting environmental issues to existing products or processes (Hughes, 2012).

Another area of mutual development concerns international standards. These certifications have been suggested as one driving force behind joint environmental and operational improvement. Companies working towards ISO 9000 (operational excellence) often naturally move on to focus on ISO 14000 (environmental excellence) – or vice versa (Kitazawa and Sarkis, 2000; Simpson and Power, 2005; Corbett and Klassen, 2006).

However, while such synergies have been observed exploiting them has often been notoriously difficult (see: King and Lenox, 2001; Rothenberg *et al.*, 2001). Reasons for this maybe the continued focus on the environment which, while obviously important, has over-shadowed a broader range of sustainability issues as well as the mixed and

Study	Finding
Florida (1996)	Zero waste and zero defect mentality of lean automatically has environmental benefits as less waste is produced, less materials needed for rework or lost to scrap, less time (therefore energy) consumed in producing an output
Romm (1999)	Found variable speed paint motors – reduced paint defects by a factor of 30 and energy consumption by 50 per cent
Klassen (2000)	Linkage between investment in JIT and environmental performance
Lapré *et al.* (2000)	JIT only to positive benefits (waste reduction) when fully implemented in the proper manner
King and Lenox (2001)	Study of 17,499 manufacturing firms found strong evidence that lean leads to waste and pollution reduction
Klassen (2001)	JIT benefits pollution prevention, and pollution and JIT strategies should go together
Rothenberg *et al.* (2001)	Lean production or JIT can reduce emission of VOCs by leading to more efficient solvent use in paints
Rothenberg (2003)	Reducing material use through "right first time" approach reduces materials used and associated power/pollution costs
Zhu and Sarkis (2004)	Empirical study of Chinese manufacturers found a clear positive relationship between green supply chain practices, quality management, JIT and economic performance
Simpson and Power (2005)	Positive relationship between lean approaches and pollution prevention
Kainuma and Tawara (2006)	Information sharing reduces bullwhip effect – reduces unnecessary production, transportation and therefore waste/pollution
Farish (2009)	Toyota UK 1993-2007 – 70 per cent reduction in energy needed to make a car (6,000 to 2,000 KWh), water usage per vehicle cut by 75 per cent (to 2 m^3), 70 per cent decline in VOC emissions, total waste per car dropped by 60 per cent to 10kg per car
Franchetti *et al.* (2009)	Baxter Healthcare – process mapping to reduce water use and cost; boeing – lean improvement led to 70 per cent drop in use of packaging materials through kanban (supplier transport to factory floor so no need for internal packaging/storage
Cabral *et al.* (2012)	Identify a clear overlap between waste reduction resultant from lean tool implementation and environmental waste reduction

Table I.
Lean operations and environmental benefit

contradictory definitions of lean operations (for instance, Mollenkopf *et al.* (2010) define lean as purely a JIT tool). These mis-definitions are problematic as a failure to classify lean properly makes it difficult to identify the true sustainability benefit and can lead to incorrect negative associations being identified. As an example, Macdonald (1991) and Sarkis (1995) both find a negative relationship between lean (defined as JIT) and environmental performance; however, a full lean implementation, which includes internal operational and external supply changes that include JIT, has been evidenced to reduce environmental impact (see: Klassen (2000) and Lapré *et al.* (2000) for evidence). Similarly, failing to acknowledge the explicit sustainability issues built-in at the strategy/policy-deployment (PD) level, overlook the explicit aspects of lean operations that generate sustainability benefits (Farish (2009) demonstrate how specific targets for issues such as energy use, emissions, and waste materials are built in to the strategy process at Toyota). It is therefore necessary to clarify the true nature of lean operations as well as to investigate the benefit (or not) of this approach across a full range of sustainability issues.

Study	Finding
Geffen and Rothenberg (2000)	Positive relationships between environmental performance and worker involvement
Kitazawa and Sarkis (2000)	Firms that move to ISO14000 (environmental standard) often reap benefits of positive employee engagement through TQM afterwards
Florida and Davison (2001)	Firms with positive environmental performance are also more innovative
Klassen (2001)	Improved environmental, health and safety aid plant productivity
Sroufe (2003)	Analysed linkages between multiple areas of CSR performance and operational performance findings distinct areas of outcome benefits – including, regularity compliance (and avoid costs of non-compliance); reduced liability/negligence cost (through better health and safety), better process and product design (for instance through a move to full life-cycle analysis which has benefit of reducing cost and improving environmental performance
Zhu and Sarkis (2004)	Environmental improvement can improve worker engagement and satisfaction
Corbett and Klassen (2006)	Environmental issues can improve financial returns by opening up new customers, competitive differentiation (and increasing market share), reducing cost through waste reduction; focus on environmental improvement may create a more systems focused approach to management generally

Table II.
Environmental improvement and operational benefit

Addressing full sustainability

A range of drivers have been identified for improvement in OM sustainability in practice: Mollenkopf *et al.* (2010) for instance classifies internal drivers (cost reduction by waste reduction) and external drivers (government or customer pressure to improve sustainability performance). However, what "sustainability" actually means is far less certain (Wagner *et al.*, 2008, p. 125). While definitions of "sustainability" are often limited to environmental concerns, a full range of issues have been identified as relevant beyond the natural environment. Conducting a meta-analysis of several hundred previous studies in the area, Piercy and Brammer (2012) identified six dimensions (environmental, workforce, supply chain, community, governance and quality issues).

(i) The environment

issues related to the impact on the natural environment of business operations, including: pollution and emissions from production and the materials used in products, energy use, emissions from transportation, use of recycled materials in production, and recycling of products post-consumption (see for instance Buysse and Verbeke, 2003; Székelly and Knirsch, 2005; Jenkins, 2006; Maloni and Brown, 2006).

A range of environmental benefits from lean production have already been identified (see above). The core premise is that producing the same output with less resources (materials, energy, capital) is inherently good for the environment while also reducing the cost of operation for the company (Florida, 1996). Similarly, by improving quality (a core lean objective) there are less production defects and resultant scrap/rework, further reducing cost and environmental impact (Simpson and Power, 2005).

(ii) Workforce issues

Related to how an organisation treats its staff. Four sub-dimensions were identified: workplace operational issues (providing a safe working environment with good working conditions), compensation (fair wages and payment), diversity issues (non-discrimination in hiring) and union relations (recognition) (see: Panapanaan *et al.*, 2003; Meijer and Schuyt, 2005; Wagner *et al.*, 2008).

Research has previously identified a positive correlation between worker engagement/involvement and environmental performance (Florida, 1996; Kitazawa and Sarkis, 2000; Sroufe, 2003). Improved working conditions are a mutual aim of lean operations and sustainability. Moving toward an engaged, empowered, and well trained workforce underpins the workplace changes in lean improvement (Storey, 1994). As a result, lean operations also tend to deliver higher levels of safety through visual management, worker training, and standardised work (Taubitz, 2010). Incentive payments and a generally higher level of pay in lean versus non-lean plants have also been observed (Womack *et al.*, 1990; MacDuffie, 1995). These factors, explicitly lean, also serve to clearly create a sustainable working environment.

(iii) Supply chain issues

Concerned how an organisation monitored and responded to the behaviour of third-party organisations beyond their ownership. This included labour practices (human rights recognition such as avoiding sweatshops or forced/child labour), treatment of suppliers by the organisation (such as paying on time and open and honest dealings) and fair trade/ethical sourcing issues (positive behaviour to support suppliers) (see: Carter *et al.*, 1999; Maloni and Brown, 2006).

Lean supply chain strategy focuses on building close, long term relationships with high levels of information transparency with suppliers for the purposes of cost reduction and quality improvement (Lamming, 1993). There is increasing evidence that close supplier relationships also improve environmental performance (Klassen, 2001). Information sharing to reduce the bullwhip effect has been observed to reduce unnecessary production, transportation, and stock holding, reducing a range of environmental impacts (Kainuma and Tawara, 2006). Close relationships also increase inter-firm innovation to reduce the joint environmental impact of all companies in the supply chain (Frosch, 1994; Florida, 1996; Geffen and Rothenberg, 2000; Simpson and Power, 2005). Part of the auditing process in supplier selection within a lean approach also includes a range of governance, ethical, and workforce issues – requiring a supply partner to operate in conformance with a wide range of sustainability objectives (Nishiguichi, 1994).

(iv) Community contributions

This related to the positive impact of the organisation in the community in which they operated, for instance, through charitable donation and positively supporting the community (see: Lee and Shin, 2010).

Maintaining a positive reputation in the local community is an explicit part of the strategy setting process within the lean organisation. This issue, while often overlooked, has been key to a range of lean organisations (Womack and Jones, 2005). For instance at Toyota, since the 1950s, there has existed a clear focus on community issues focused directly on operating communities of current and former sites and employees. These issues are not just statements of principle but associated with clear performance metrics (Toyota, 2011).

(v) Governance and ethics

This concerned issues related to the management of corporate activities, including: socially responsible investment, public disclosure of activities, having a clear and written ethics policy, and ensuring legal compliance (see: Maignan and Ferrell, 2000; Kok *et al.*, 2001; Turker, 2009).

Transparency of information within the firm and across firm boundaries underpins these sustainability issues. The shift toward this transparency is also fundamental in any lean organisation (Lamming, 1993). Standardised work routines, and clear communication channels to employees, suppliers, and customers, are all elements of a lean operation (Womack *et al.*, 1990). This transparency supports internal governance practices, as well as reducing wastage at the firm boundary as only those resources that are needed are pulled into the firm avoiding the bullwhip effect (Corbett and Klassen, 2006; Kainuma and Tawara, 2006).

(vi) Product and service quality

This related to ensuring products were safe and fit for purpose, of good quality, and that marketing activities were honest (see: Graafland *et al.*, 2004; Anselmsson and Johansson, 2007; Turker, 2009).

This area is perhaps one with the clearest overlap between sustainability and production operations – improving product quality. One of the primary goals of lean operations is to improve product quality (Womack *et al.*, 1990). In addition, open and honest communication with customers is equally important (Womack and Jones, 2005).

In this study the focus is on all areas of sustainability, therefore it is necessary to relate all six dimensions of sustainable operations to lean operational activity. In doing so it is possible to see a clear overlap in approach/intent between lean and sustainable operations (see Figure 1).

In summary, from reviewing the past literature in both areas of lean improvement and green/sustainability an evolutionary development is apparent (shown in Figure 2).

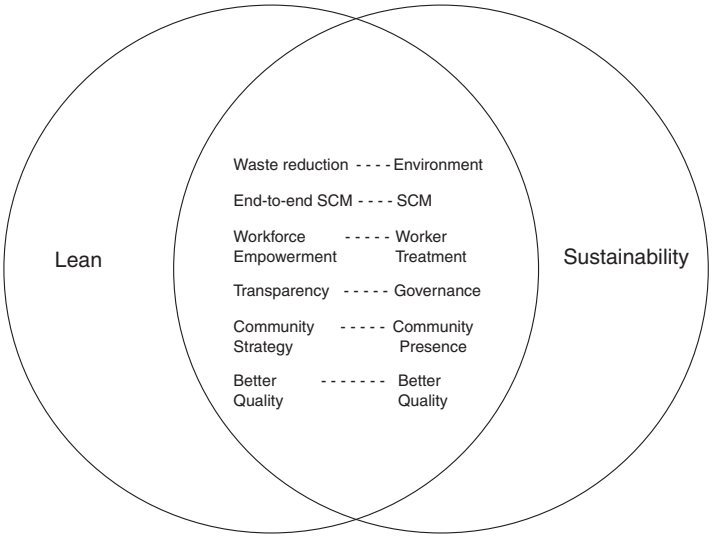

Figure 1.
Lean and sustainability

Early work on lean operations (Womack *et al.*, 1990; Womack and Jones, 1996) extended to focus on entire supply chains (Lamming, 1996) and later to look at the introduction of green principles into internal lean operations (e.g. Ho, 2010a). Moreover, early work on green business (i.e. environmentally focused) (e.g. Peattie, 1997) lead to a later focus on the environmental impact of entire supply chains (e.g. Brammer and Walker, 2011), which was matched by parallel moves to investigate how green and lean approaches could be combined inside organisations (e.g. Hines, 2011). Work on lean and green, in common with early work on lean thinking, has, in the last two years, seen a move from a focus on internal operations to external supply chain development (e.g. Carvalho *et al.*, 2011). As environmental research broadened into a focus on general sustainability (e.g. Sroufe, 2003) this too has started to feed in to lean supply chain design. We are only now witnessing the first publications that bring lean improvement together with a full sustainability agenda (e.g. Azevedo *et al.*, 2012).

The few existing publications in the area of lean-sustainability (e.g. Ho, 2010b; Prasad and Sutharasan, 2012; Zokaei *et al.*, 2013) have a tendency to stop short of looking at all sustainability areas – through no fault on the authors part but because there exists no universal definition of sustainability on which they can build. Azevedo *et al.* (2012) are one of the first to consider how lean fits with broader sustainability issues beyond just environmental or waste impacts and investigate corruption, supplier screening (including governance/labour standards), and local supply issues (including community contributions). Although their study is an important contribution in defining this area, as an exploratory investigation, it covers only one company within the automotive sector, rather than a cross-industry study. Indeed, the authors indicate a clear agenda for future research to: investigate motivation and barriers to lean/sustainability implementation; develop broader measures to capture sustainability activity in parallel to lean; investigate how lean/sustainability activities occur outside of the automotive sector; and expand initial findings with multi-case investigations.

It can be proposed that lean operations, when properly defined and understood, have the potential to address a wider range of sustainability issues; however, more empirical research is needed to fully address the benefits of lean operations for sustainability as well as examining the complex inter-relationships between lean and sustainability, which while previously suggested (e.g. Florida, 1996; Azevedo *et al.*, 2012), have never been fully explored across a range of industry sectors and case studies. Thus, we address one key research question:

RQ1. What is the relationship between improvement driven by lean operations and improvement driven by sustainability objectives?

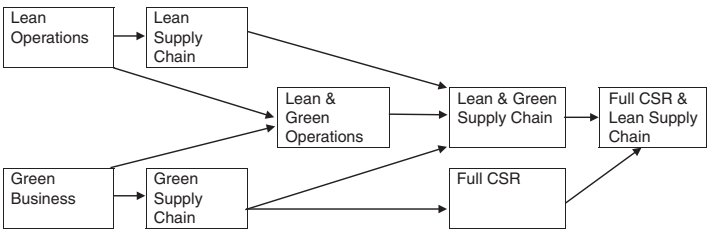

Figure 2.
Evolution of lean and sustainability in operations/supply chain research

Research methods

This research seeks to evaluate the use of lean approaches in developing positive sustainability outcomes environment. There is currently little empirical knowledge about lean application in this context; hence, the research reported in this paper is exploratory. The lack of validated knowledge in this area and the inability to fully describe such systems with quantitative investigation presents a requirement for qualitative analysis to fully describe the complex and often chaotic system at work. The use of the case-study as a research tool for exploratory investigation and to generate new understanding is well established within social science research (Voss *et al.*, 2002; Yin, 2008). The researchers adopted a critical realist position as a way of combining the ontological strengths of realism with the epistemological value of both positivism and anti-positivism (Mingers, 2001).

The use of single or small numbers of case studies as knowledge building tools is increasingly prevalent in the OM literature (for instance: Waring and Wainwright, 2002; Acur and Englyst, 2006). To improve rigour in OM case research, Stuart *et al.* (2002) and Voss *et al.* (2002) recommend similar frameworks, each of which follows several distinct phases: definition of the research question; selection of cases; development of a measurement instrument; data gathering; data analysis; and, results dissemination.

The research question, developed from a conceptual review of the literature, has been stated: "What is the relationship between improvement driven by lean operations and improvement driven by sustainability objectives?" To address this question it was necessary to select companies for investigation who were experienced in lean and sustainability. The criteria for selecting each case company were driven by the research questions rather than random sampling (Eisenhardt, 1989; Yin, 2008). Initial discussion with a range of companies identified two trajectories: companies that adopted lean and then later invested in sustainability versus companies that adopted sustainability practices and later employed lean improvement. Three cases in the former group and two in the latter were recruited. The use of multiple cases, with different trajectories, allows for some degree of triangulation in the research (Easterby-Smith *et al.*, 1997).

The study was conducted between 2008 and 2012 and involved studying the operational practices of five companies. All companies are in the manufacturing sector and all studies were conducted within UK-based facilities. To ensure a cross-comparative research study, a common context was necessary and the manufacturing sector was chosen. This sector was more advanced than services in lean and sustainability adoption (Piercy and Rich, 2009) supporting the ability for a longitudinal investigation. While the physical product and market differed, each company had a relatively small number of plants and employed relatively common change methodologies. The sample reflects the range of sectors and change drivers of past studies in this area (e.g. Florida, 1996) and is outlined in Table III.

The lean improvement activities at each company were implemented by an independent consultancy team. The role of the research team was as observer of the improvement process. Observations included: semi-structured interviews with managers, technical specialists, staff, and customer groups (45-120 minutes); observation of process mapping and problem solving workshops; auditing of company reports and ISO submissions. Key respondents were interviewed on more than one occasion and asked to comment (where appropriate) on others' observations and opinions. The interviews can be seen as active interviews seeking to

Table III.
Study case companies

	Company	Industry	Size (employees)	Operating sites (*n*)	Improvement trajectory	Period of study (months)	Primary interviews	Primary investigations	Secondary data materials
A	CosmeticCo	Cosmetics manufacture	600	2	Lean first	48	3 customer 15 managers 7 inspectors 18 shop-floor	6 process maps 3 problem solving workshops	14 audits, inc. ISO 14000 survey Audit of company training materials
B	PharmaCo	Pharmaceutical manufacture	140	1	Sustainability first	24	3 customer 6 managers 12 operators 3 engineers	3 process maps 1 problem solving workshop Facilitated learning group	Audit for ISO 14000 and 9000 Audit of company training materials
C	MetalCo	Metal pressing manufacture	500	1	Sustainability first	36	6 customer 8 general managers 14 technical managers 16 operators 4 inspectors	12 process maps 8 problem solving workshops	Audit for lean, health and safety, SA8000 Audit of company training materials
D	DrinkCo	FMCG manufacture	2,000	8	Lean first	12	3 customer (wholly owned subsidiary) 5 managers 12 operators and logistics staff	9 process maps 1 problem solving workshop	Audit for ISO 14000 Audit of company training materials
E	FurnitureCo	Furniture manufacture	600 (UK)	1 (UK)	Lean first	36	3 customer 4 manager 3 team leaders 14 line operators	3 process maps 3 problem solving workshops	2 lean audits

be reality-constructing and meaning-making occasions (Holstein and Gubrium, 1995). These interviews contained three types of questions:

(1) main questions to begin and guide the interview;

(2) probes to complete or clarify an answer or ask for further examples; and

(3) follow-up questions to pursue implications of answers to main questions.

Interviews were transcribed close to the interview and where permitted tape recordings were used. Whilst it is impossible to guarantee absolute impartiality, every effort was made to maintain neutrality during the interview process. Response bias is difficult to avoid, especially as the topic under discussion was highly sensitive to some. Interviewer bias may occur when the researcher imposes his or her frame of reference on the interviewee, when questioning and interpreting answers (Easterby-Smith *et al.*, 1997). To avoid leading respondents, the interview guide was carefully considered by a number of academics to ensure questions did not simply elicit socially desirable answers (Gummesson, 1991).

Before analysis all data sources were coded based on a two-phase procedure. Initial coding used a process known as open coding which essentially "describes" the development of each intervention based on critical events. Axial coding was then used to group codes with similar characteristics into broad categories related to the guiding research questions. The coding process was an iterative one with several rounds of sorting over several weeks. To improve the reliability and validity of the results interim findings (including potential differences of interpretation) were presented in a series of working documents, giving participants an opportunity to question the initial conclusions drawn. Given the sensitivity of the material under investigation confidentiality was a key factor in ensuring "open and honest" dialogue, thus some of the data has been disguised and no individuals have been named.

Findings

(i) Transformation journey: lean-first companies

CosmeticCo was founded in 1996 and operates as a subcontractor-filler for branded cosmetics. They produce 6,000 stock keeping units (SKU) over six product families. At the start of the lean transformation (ca. 2005) they maintained two total accounts but had grown to 44 within three years. The top nine accounts covered the majority of production volume, ranging from large retailers (e.g. Tesco) to products for high-end fashion houses. The primary concern of all customers was price sensitivity driven by the cost-to-fill each bottle. The company started a lean improvement programme to reduce costs and production time. This was initiated at the workplace level, involving human resource issues (moving to team-based working, increased training, empowerment, and foundation of a works-council to represent worker interests) as well as systems issues (implementation of a visual workplace, work and part standardisation, batch reduction, and plant cleanup and re-layout); this grew to focus on the supply chain (involving consolidation of the supply base and moves to close long term relationships, as well as ending dealings with supply partners in the third world). The lean approach became integrated through PD at the strategic level. The PD process identified positive sustainability performance as a potential selling-point for customers and drove the sustainability agenda across the company, focused firstly on forming a coherent strategy that was rolled out to the workplace (waste reduction and process redesign), then on to suppliers (positive sustainability activity through supplier audits).

At the end of the process benefits included significant growth of customer accounts (two to forty-four in three years) and operational benefits that included much faster stock turns (move from 4/year to 24/year), defect reduction (inbound supply by 50 per cent, labelling by 80 per cent, lead time by 80 per cent). In parallel they had improved the health and safety of the workforce, empowered them, increased skills, and supported positive change across the supply base.

FurnitureCo is a one hundred year old company, but only entered the UK market in the 1980s. They are a manufacturer of high-end furniture products, primarily for the B-2-B marketplace, selling to architects/designers for the fit-out of office buildings. They provide approximately 40 different products, each with a range of customisation options. They are one of the dominant operators in their marketplace in the UK, primarily competing with smaller UK companies or large international manufacturers. The UK division invested in lean from 2000, and are now the most advanced lean operator of the case group. Their focus on lean improvement was dictated by the overseas corporate office, where the driver was the need to increase profit margins through efficiency gains (their production already offered high quality). Their lean journey focused on significant changes in the workplace (operator training, standard work, improved safety practices, 5-S cleanup of plants) followed by changes to the supply chain in UK, Europe, and Asia. Supply consolidation reduced suppliers in number by one-third, to eight. Some parts were only available from third world suppliers so these remained in the supply chain; however, they were heavily audited for quality and general performance. All suppliers were integrated into the business in a transparent manner (through a shared information system and open-book costing) and broader stakeholders were engaged with community activities such as sponsorship and giving. Waste reduction was a major focus of the lean programme, including cradle-to-grave design to allow reuse of parts and recycling/cradle-to-cradle design. Lean initiatives were integrated at the strategic level with extensive PD from the corporate to shop floor level, widely using x-charts. In 2009 the PD process within the corporate office led the refocusing of the business around the notion of positive-sustainability performance as it identified this as a potential selling point to customers and end-users. Operational improvements included line-speed increases of 10 per cent each year, defect reduction to low PPM levels, and reduction in stock holding from 1-month to 1-week. The sustainability programme formed the foundation of the company's sales strategy, primarily using the achievements of the previous lean transformation (waste reduction, supply chain engagement, community presence) to sell the company as a top sustainability performer.

DrinkCo is a relatively small manufacturer of beverages and operator of hospitality venues. They oversee four production facilities, each with its own distinct brand. Each facility can produce up to a dozen different products. Company sales are split 45:55 between general retail or wholesale and their own distribution channel to wholly owned hospitality outlets. Their lean journey began relatively recently (2010) and was driven by a need to improve production efficiency to release cash-flow for expansion. At the start point their production was constrained by unreliable machinery that created a barrier to the expansion the company desired. The company followed a process of production line transformation with new equipment and practices (including worker engagement, up-skilling, union engagement, review of safety practices to cut down-time, and extensive use of TPM). Lean change was relatively quickly fed-forward into their own distribution channel and back to suppliers (UK based). As most suppliers were already locally based, changes focused on improving transportation costs

(new, more efficient vehicle fleet), recycling of broken goods (the company is dominated by glass-based containers so breakage here is a major cost), and promoting outlets in the community to drive in business (through local sponsorship). The company is currently beginning the process of integrating lean into their core operating strategy. The company began real investment in sustainability shortly after the lean transformation process began. As part of their desire to expand they identified positive sustainability performance as something that could appeal to potential investors. Many of the sustainability initiatives were piggy-backed on the lean improvements (e.g. recycling glass for waste reduction was promoted both as a lean and sustainability gain). Operational improvements included 50 per cent reduction in accidents/near-misses in the workplaces, improved production reliability (reduction in stock-outs), and increases in service quality (as outlet managers were not focused on dealing with stock problems).

(ii) Transformation journey: sustainability-first companies

PharmaCo is a relatively new company, founded in 2005 as a green-field division of an older (ca. 20 years) company. They are a niche provider of medical/pharmaceutical cosmetic products in tubes, tubs, and vials. The company supplies three major customers, operating 52 SKUs with approximately 26 products, each available in two sizes. The company operates three production lines that are highly controlled (e.g. by US Food and Drug Administration regulation). From the beginning the company management team sought to identify what a world-class business in this sector would look like and to build it. One key area they identified was that it should be a positive member of the global community, delivering good performance across a range of sustainability areas, that included the local community (sponsorship of local charities, engaging schools, and supporting STEM education), the workforce (training, up-skilling and promotion from within, and providing interest free loans and free crèche facilities), supply chain (moving to local sourcing and not allowing third world companies to enter the supply chain, ensuring supplier conformance through three sustainability audits per year, and engaging in supplier collaboration), environment (focused on low energy use by design and zero end-of-life loss to landfill) and quality (being "second to none" in the industry). These activities supported a positive and engaged workforce. Three years into production the company, despite being highly profitable, identified that production efficiency was below the level of their major competitors (55-65 per cent line capacity vs 75-80 per cent at competitors). Based on the previous experience of several of the management team in lean improvement, a lean transformation initiated, focused first on the workplace level (although heavily constrained by regulatory procedure), with moves to specific lean and TPM worker training, and standardised batch sizes and containers, then rapidly expanded to the supply chain to ensure quality in. The company is currently at the start of a PD implementation phase but has already realised 66 per cent lead time reduction from lean implementation (order-to-completion cut from six to two weeks and waste reduction of 5-10 per cent).

MetalCo is one of the older sample companies, founded in 1969. They operate as a contracted metal pressing operation, with 250 SKUs operating on three production lines. Not all SKUs are offered at any one time, and line changeovers occurred between once to twice a week (before improvement). The company serves 52 customers, with the top three accounting for 60 per cent of production volume. The driver for all customers is perfect quality in high volume production at a good price. Their investment in

sustainability started in 2003 in response to a major environmental failure (pollution of drinking water). The response-to-crisis team identified that there were potential gains not just from fixing this problem but addressing general improvement in environmental and sustainability performance. This identification formed part of an explicit new strategy to promote positive sustainability activities across the company, in environmental terms (to reduce emissions and waste), workforce treatment (to positively engage the workforce – for instance with training on carbon awareness and problem solving to reduce production line waste), supplier engagement (to reduce environmental impact of the entire supply chain), local sourcing (30 per cent of materials inbound from within 25 miles to reduce transportation impact), and being a positive force in the community (engaging schools and supporting local charities). In 2009 as part of the audit/improvement in sustainability, it was identified that production efficiency was a major failing of the company (creating wasted materials/energy consumption and pollution). The company adopted a lean approach to improvement, focusing first on the production lines (engaging workers with training to support a visual workplace, and implementing quality improvement and TPM), then expanding this to the supply of materials inward (supply base consolidation, move to partner working, discontinuing third world sourcing, and hosting supplier open days and associations), and are committed to integrating PD into the strategy of the company within one years time. Lean benefits already realised include 35 per cent improvement in operating efficiency, a five per cent reduction in costs and 10 per cent released capacity.

(iii) Transformation commonalities

All three lean-first companies followed a common lean change trajectory of improvement at the workplace level, which flowed into change in the supply chain before eventually becoming integrated at the strategic level of the company. Their shift to move from lean to sustainability was driven by a common notion of increasing the appeal of the company to target stakeholders. In two-cases (CosmeticCo, FurnitureCo) this was specifically identified by the PD process, while the other company made the shift based on general management analysis and change. In implementing sustainability, a clear top-down strategy that fed through to parallel (rather than stage based) improvements at the workplace, supply chain, and in the local community was observed. In one case the workplace changes directly identified the need for operational improvement (MetalCo), while in the other there was general awareness of the need for change that lead to lean improvement.

The detailed activities of each transformation are shown in Table IV (for lean-first cases) and Table V (for sustainability-first cases). The tables outline how for the lean-first cases many sustainability objectives were realised as part of the lean programme, and, conversely, how for the sustainability-first cases many of the lean improvements already had foundations in place. As can be seen most of the cases followed a very similar transformation process despite operating in different industries and undertaking change with different consultant groups.

(i) Lean-first transformation: overlapping outcomes. At the workplace level each company undertook an individual selection of lean tools suited to their business (process mapping, 5-S cleanup, visual workplace, standardisation, plant re-layout, TPM, and so on) but all built upon a common core of worker engagement with the frontline workers driving forward most of the improvement processes. To enable this to take place significant investment in training the workforce was needed – this was focused not just on lean improvement but also general education (for instance

Table IV.
Summary of lean transformation activities

Lean improvement activities	Lean-first companies CosmeticCo	FurnitureCo	Sustainability-first companies DrinkCo	PharmaCo	MetalCo
Workplace improvements					
5s cleanup	×	×	×	×	×
Visual workplace	×	×	×	×	×
Ergonomic redesign					Pre-existing (Sust Prog)
Standardisation	×	×	×	×	×
Worker engagement	×	×	×	Pre-existing (Sust Prog)	Pre-existing (Sust Prog)
Works council	×	Engaged union	Engaged union		
Re-layout/redesign	×	×	×	n.a. – new plant	Pre-existing (Sust Prog)
Community engagement	×	Not until better-world	×	Pre-existing (Sust Prog)	Pre-existing (Sust Prog)
TQM	×	×	×	×	×
TPM	×	Very low	×	Very high	×
Andon/line stop	×	×	No	×	no.
Waste reduction	×	×	×	Pre-existing (Sust Prog)	Pre-existing (Sust Prog)
Supply chain improvement					
Local sourcing	×	×	Pre-existing	Pre-existing (Sust Prog)	Pre-existing (Sust Prog)
End third world out-sourcing	×	Maintained but heavily audited	None ever available	None by design	Pre-existing (Sust Prog)
Close supplier relationships	×	×	×	Pre-existing (Sust Prog)	Pre-existing (Sust Prog)
Open-book costing	×	×	×	Pre-existing (Sust Prog)	Pre-existing (Sust Prog)
Support supplier internal improvement	×	×	×	Pre-existing (Sust Prog)	Pre-existing (Sust Prog)

(*continued*)

Table IV.

	Lean-first companies		Sustainability-first companies		
Lean improvement activities	CosmeticCo	FurnitureCo	DrinkCo	PharmaCo	MetalCo
Positive community engagement	×	Not until better-world.	×	Pre-existing (Sust Prog)	Pre-existing (Sust Prog)
Information systems integration	Kanban rather than IS	×	Ongoing for major partners	Kanban rather than IS	IS with major partners
Flow production	×	×	×	×	×
Demand amplification reduction	×	×	×	×	×
Strategy changes					
Policy deployment	×	×	About to start	×	About to start

Sustainability objectives and activities	Sustainability-first		Lean-first		
	PharmaCo	MetalCo	CosmeticCo	FurnitureCo	DrinkCo
Workplace	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Positive working environment	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Training/up-skilling	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Ergonomic workplace	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	No
Supply chain					
Move to close relationships	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Local sourcing	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Always favoured
End of third world sourcing	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Never used
Joint development	×	Not until lean	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Cost sharing	×	Not until lean	Pre-existing (lean prog)	No	No
Sustainability audits	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Secondment/staff exchange	×	Not until lean	Pre-existing (lean prog)	No	No
Interest free loans	×	×	Pre-existing (lean prog)	No	No
Community					
Sponsorship of charities/sports	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Engagement with schools	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Business mentoring	No	×	Pre-existing (lean prog)	No	No
Environment					
Energy use reduction	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Materials use reduction	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Waste reduction	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Transparency					
Open-book costing	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	No
Stakeholder transparency	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)
Quality					
Focus on "best possible" quality	×	×	Pre-existing (lean prog)	Pre-existing (lean prog)	Pre-existing (lean prog)

Table V. Overview of sustainability activities

CosmeticCo observed low literacy of workers so founded a learning centre). The major benefit of worker engagement was to use their knowledge to improve the quality and reduce the waste along each stage of the production process, something all companies achieved (e.g. at PharmaCo an operator led redesign of a labelling machine to reduce changeover time from 30 to three minutes by attaching new label runs to the end of the old run to avoid rethreading the machine). Positive sustainability outcomes of the workplace changes were empowerment of the workforce, engagement and support from (often previously hostile) unions through improved pay/conditions, and workplace redesign that made the workplace safer (e.g. DrinkCo saw accidents drop by 50 per cent from lean redesign) and also more pleasant (e.g. CosmeticCo had an aging workforce and used a 5-S activity solved many ergonomic problems they encountered). The environmental benefits of waste reduction were also significant (e.g. at CostmeticCo lean changes led to a 30 per cent reduction in landfill in a year as over-sized batches used to protect from defects were eliminated through quality improvements). When the companies moved toward sustainability programmes the lean waste gains were rebranded as sustainability gains:

> Lean is just the way we work around here. It is a corporate initiative and we have squeezed every last ounce of improvement out of the production process. We have very quick turnaround of products and we invest quite a bit in our staff and their improvement skills (Operations Director, FurnitureCo).

At the supply chain level all cases undertook similar changes: supply base consolidation to fewer suppliers, physically nearer, with long term close, collaborative relationships. The lean benefits focused on quality improvement (e.g. CosmeticCo saw inbound defects cut by 80 per cent in some areas). There was also significant waste reduction (e.g. demand amplification mapping at DrinkCo reduced wasted stock while FurnitureCo cut stock holding from one month to one week). Part of ensuring the quality of suppliers was to move away from low-cost third world companies to focus on relatively close companies and forming close relationships with them (or where a third world company was retained – only in FurnitureCo as no European alternative was available – a significant audit and partnership agreement was put in place). At the supplier interface the aim was to improve information flow to improve product quality – for instance, three case companies (CosmeticCo, DrinkCo, PharmaCo) moved to open-book costing – sharing previously proprietary cost information with suppliers to ensure they got honest cost/quality specifications in returns. Part of supplier relationship management under lean required frequent auditing of supplier plants (two to three times per year) and included clear sustainability criteria (e.g. CosmeticCo audited suppliers for environmental, morale, and safety performance as part of lean auditing). There are again many sustainability benefits of these lean improvements in terms of general transparency of operations, reduction or elimination of dubious third world labour practices, and increased local sourcing.

Community engagement was a core aim of each of the lean-first companies. On one level the community was seen as a stakeholder in the supply chain and also the main resource base where workers were drawn from. While the companies engaged with schools (e.g. CosmeticCo ran STEM courses on-site for local schools) and the community in general, the greatest use of community engagement activities was as an incentive for workers. For instance, at MetalCo, in exchange for committing to continuous improvement workers were allowed to allocate some of the cost savings

to a local charity of their choice. In this way all companies undertook significant sponsorship of local charities. The lean aims were part of the lean agenda of being a positive member of the community and, from a self-interested perspective, to support worker engagement. As with environmental improvements, when the three companies adopted sustainability issues the community activities were simply rebranded as sustainability activities and continued.

At the strategy level, FurnitureCo had the longest standing policy deployment approach, with CosmeticCo having a similarly designed process. Through PD both companies had identified that positive sustainability performance could be a major selling point for the organisation (while DrinkCo came to the same conclusion but outside of PD). Thus, for these companies positive sustainability can be seen as a direct goal of the lean strategy process that became ingrained in each company:

> Our lean journey provided a lot of evidence that we were making a difference in terms of yield losses and operating losses. When we looked in more detail we found these aligned with better environmental management and so we claimed our lean journey to provide green benefits to the business (Operations Director, CosmeticCo).

(ii) Sustainability-first transformation: overlapping outcomes. It was clear from the case studies that there were operational benefits of sustainability programmes. Focusing on environmental improvement in each company was predominantly led from the workplace, with frontline workers trained in process improvement and tasked with finding better ways of production (e.g. MetalCo posted targets in the canteen for staff to track). While the companies also undertook large scale top-down changes (e.g. DrinkCo changed transportation policy so that all shipping was done at night so lorries were not stuck in congestion thereby reducing emissions and saving fuel costs), most changes were worker-led (e.g. at MetalCo moving from polystyrene packaging to paper or reusable linen). Changes at the workplace were an area where the sustainability driven improvements had major overlap with a lean agenda, with both focused on creating a positive, safe, and engaging workplace. This included improving terms and conditions and providing worker support through items such as interest free loans (PharmaCo) or subsidising child care for female workers (MetalCo) and extensive training (60-hours per year at PharmaCo). MetalCo provided relatively low skilled workers with process improvement training to support them walking production lines and brainstorming ways to reduce waste, while PharmaCo employees were guided in engineering-led improvements. When each company later moved to lean improvement these initiatives paid dividends – each were able to move quickly forward with lean process improvement and adopt relatively advanced lean approaches (TPM) with the workforce as they were already positively engaged, trained on process improvement, and used to leading change.

Both sustainability-first companies were focused on improving the performance of their supply partners on a range of sustainability issues. This involved discontinuing relationships with third world companies with questionable practices (e.g. MetalCo aimed to increase local supplier sourcing to 30 per cent of goods-in, and moving to more transparent relationships and information sharing at the firm boundary). There was also a clear long term partnership approach at PharmaCo:

> […] we build relationships and this is one area of supply chain management we all agree on – we must do our bit to improve and reduce wastes like our carbon footprint. Actually, we have found this a very good subject to engage with suppliers (Purchasing manager, PharmaCo).

Such close relationships have always been an objective of lean improvement, not for sustainability issues but to improve quality. When the two companies came to lean improvement the supply chain changes that lean dictated had already been largely completed as part of the sustainability agenda.

Both companies undertook extensive work with their immediate community (e.g. PharmCo helped the local elderly care home cover Christmas food shopping, while MetalCo was active in promoting science/engineering as a career to female high school students). These actions were taken based on a belief that the company should be a positive force in the community: "One of our key values is sustainability and we wholeheartedly believe it is good for our community and our business" (MetalCo Operations Director). In this spirit, each company undertook to offer good quality products and engage in open and honest dealings with customers. There was a clear pay off in lean change for these actions: the positive reputation of the companies ensured workers were not concerned about job losses or plant closures.

(iii) Next-generation products. For both groups of case companies there was the emergence of a clear tipping point – existing products and associated existing production facilities could only generate improvement to a finite degree. Without a new product, or different production process for an existing product, there were only so many small changes that could be made before it was necessary to reconsider the nature of the product and/or production process:

> We rapidly found that lean and sustainable initiatives for production reached a point where we were better off changing product designs than tinkering around the edges (General Manager, ChairCo).

The constraints of existing methods of working, in terms of existing supply partners, materials, production requirements, and workforce activities, meant that improvement stalled until new approaches were introduced. Take for example the ability to improve sustainability and cost performance of one-use plastic vessels – with the inability to reduce costs of plastics, improve material recycling, or to handle different sized vessels or different materials on a filling line, no improvement can be realised (e.g. DrinkCo). Only when a new product or production process is designed, can improvements be made – for instance, introducing larger metal or glass vessels that can be reused over several generations. This change requires new machines, logistics and transportation, training of product staff, and educating end consumers. These activities are costly in the short-term but offer long-run benefits for the organisation and for sustainability performance. Nevertheless, such costs are usually only tolerated during a new product introduction.

Such change activities are often dependent on the nature of the product – in commodity manufacturing where demand is stable over time (e.g. a lipstick at CosmeticCo) there is less opportunity for new product introduction (packaging and marketing may change but the core product is largely the same over many years). In such industries, large changes to the production process will be independent of new product introduction – this usually only occurs where there is a financial imperative (e.g. high costs of production with low quality at CosmeticCo) or significant sustainability problems (e.g. environmental pollution from poor production control at MetalCo).

The benefits of new production processes are common for both lean and sustainability agendas, in terms of: improved product designs requiring less materials (waste and cost benefits); fewer stock buffers (waste and cost benefits); less rework (waste and cost benefits); closer suppliers and development of supplier associations or

parks (providing better control over supply chain activities, community and quality benefits); and, improved worker safety through better process design (improved workforce and quality/cost benefits). This process is illustrated in Figure 3. Here it is shown that improvement can only reach a finite level with the existing product/process generation. Only when new generation is introduced can the next step change in improvement be realised. Once the next generation of products becomes embedded over time, improvement will again reach a plateau and the next step change will occur with a new generation (generation 3), with associated performance drop off of generation 2 as production is slowly phased out. Over time, this process of continual-step change provides the basis for long-term continuous improvement in sustainability performance, in the same way that this process has occurred in long-term lean organisations such as Toyota to improve quality/cost performance.

Discussion: lean and sustainable operations

It is clear to establish from the case data that there was a high level of commonality in lean and sustainability improvement programmes (joint benefits are summarised in Table VI). Both approaches shared a common philosophy on holistic, systems wide improvement, driven from a positive workplace. They also shared many of the same tools: problem solving, team working, production inspection, and training. As a result the lean-first companies found it easier to implement sustainability practices than sustainability-first cases and conversely sustainability-first companies found it easier to implement lean than lean-first companies.

It was clear that lean improvement provided a foundation for sustainability improvement. All three lean-first companies rebranded and sold their positive lean outcomes as sustainability outcomes to clients and investors – having already achieved many of the outcomes that sustainability would generate they were able to easily exploit them with simple rewording of their achievement:

> The sustainability strategy joined up lots of existing lean programmes that had positive-sustainability benefits including employee engagement, safety improvement, waste reduction on production line, recycling, and community engagement (Senior Manager, DrinkCo).

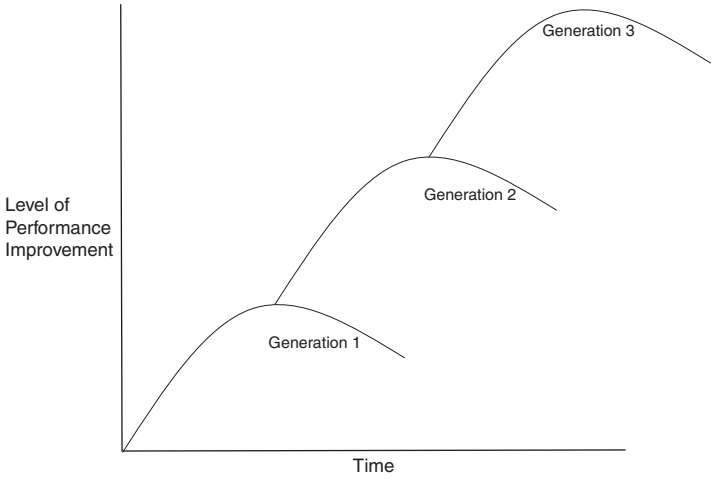

Figure 3.
New product generations and performance improvement

Table VI.
Mutual benefits of tools and activities

Activity	Occurs in lean improvement	Occurs in sustainability improvement	Lean benefit	Sustainability benefit
Workplace changes and waste reduction/quality improvement				
Worker engagement (up-skilling)	Y	Y	Understand costs of poor quality and how to fix	Engagement, treatment
Visual workplace (5S, general visual management)	Y	N	Improve quality/layout/safety	Improve safety, improved ease of work life
Works council (CosmeticCo)	Y	Y	Gain worker buy-in for lean change	Engagement, treatment
Standardisation	Y	N	Increase cross-skill of workers to work across plant; Find best ways of operating	Safety
Process mapping	Y	Y	Shows ineffective parts of production, waste, engages workers	Waste reduction
Team-working	Y	Y	Reduce reliance on inspection to enforce quality	Worker engagement, improved workplace
TQM/problem solving	Y	Y	Engage workers, find solutions to problems	Engage workers, improved workplace
Waste reduction (better quality in, better quality production, less rework, scrap)	Y	Y	Quality improvement. Cost improvement. Productivity improvement. Reliability improvement	Less energy consumption. Less material consumption. Less pollution/waste
Plant redesign	Y	Y	More efficient/quality layout	Better, safer working environment
TPM	Y	N	Focuses on wastes and cost	Focuses on waste reduction based on machine
Quick changeover	Y	N	Run smaller batches	Reduce material losses from changeover (waste)
Kanban	Y	N	Regularise system (cost)	Reduce material waste
Community activity				
Community engagement	Y	Y	Gain reputation as employer of choice to get best workers	Positive member of community
Charitable giving	Y	Y	Incentivise staff for improvement	Positive member of community
School/neighbour engagement	Y	Y	Be good corporate citizen	Positive member of community

(*continued*)

Table VI.

Activity	Occurs in lean improvement	Occurs in sustainability improvement	Lean benefit	Sustainability benefit
Supply chain				
Local sourcing policy	Y	Y	Better control of quality/cost	Ensure positive practices in suppliers
Supply chain consolidation	Y	Y	Better quality inbound at reduced cost and increased reliability	Better ability to control activities beyond boundary of firm
Local sourcing where possible	Y	Y	Better quality/cost control	Better control of sustainability actions of supplier
Close supplier relationships	Y	Y	Long term commitment from supplier to company for quality/cost improvement	Better control of sustainability actions of supplier
Supplier associations	Y	Y	Joint problem solving and development	Better control of sustainability actions of supplier
End third world outsourcing	Y	Y	Better control, partnership, quality	End risk of sustainability abuses in third world suppliers
Flow production	Y	N	Less money tied up in stock. Better quality inbound	Less environmental impact of transportation
Transparency				
Transparency to suppliers – open-book costing	Y	Y	Gain supplier commitment to long term relationship. No unexpected price rises/ problems of low price bids	Better business ethics/engagement
Transparency to employees	Y	Y	Employees understand cost/benefits to help improve	Better business ethics/engagement
Transparency to community	Y	Y	Community understands and supports business	Better business ethics/engagement
Sustainability audit and public disclosure	Y	Y	Part of transparency/audit culture	Ethical/stakeholder engagement
Quality				
Focus on quality improvement (reduced defects, improved productivity)	Y	Y	Make better products at lower cost to increase profitability	Customer gets reliable quality
Focus on honest engagement with customer	Y	Y	Trusted company can sell more	Ethically should be honest with customers

> I think being lean and green is totally compatible – we use less of everything to make products and we have no waste either (Operations Management, MetalCo).

Equally it was clear that sustainability programmes provided a foundation for lean improvement. The natural correlation of waste reduction with environmental improvement was just one facet of this, with broader sustainability items of supplier engagement, workplace engagement, and transparency all supporting later lean activities:

> The approaches are mutually compatible; we certainly see no conflict in them (Operations Manager, PharmaCo).

From a systems perspective, lean provides social-foundation for sustainability and pairs it with a technical-system to implement improvement while sustainability provides a social-foundation for lean but often lacks the technical-system toolkit element to drive forward improvement. Lean generated many visible in-plant benefits to gain support whereas many of the achievements of sustainability were less tangible and therefore harder to use as a platform for further improvement. The start of lean improvement was often quite inward looking (workplace focused), while the start of sustainability programmes were broad (to serve as focal call for improvement) but often lacked focus. Thus, lean and sustainability programmes can work well together when combined to address shortcomings in the other approach:

> I think we started with lean because it focused on the value adding process – it stabilised what we were doing and got everyone involved with something concrete; sustainability seems so vague and woolly (Lean Promotion Office, CosmeticCo).

The question arises as to whether, due to the mutuality observed, sustainability improvement will automatically lead to lean improvement and, conversely, if lean improvement will automatically lead to sustainability improvement.

Clearly from the case studies lean implementation contained many explicit sustainability objectives and it could be considered to be inherently a sustainability programme in itself. Further, the PD process identified sustainability as a key area to sell to customers. Thus, it would be fair to conclude that lean is both sustainable in and of itself and that it should, when fully implemented, lead to a full sustainability programme far beyond the environmental/green benefits that past research identifies (e.g. King and Lenox, 2001; Simpson and Power, 2005). Returning to the original research question, it was clear that lean approaches supported an evolution toward a full range of sustainability outcomes through both their content and process of implementation.

Considering the sustainability-first cases, while all did undertake lean programmes, an automatic progression was not observed. The innovation to drive forward the business on sustainability could be seen as a common driving force to adopt broader innovations such as lean (which would be consistent with Florida's (1996) hypothesis); however, there remain well known examples of highly pro-sustainable companies such as the Body Shop who maintained highly inefficient and failing operations facilities (Piercy, 2008). While there was no trade-off from lean versus sustainability there was no automatic progression – this was dependent on the desire and knowledge of the senior management team of the organisation.

From this research it is possible to specify a theoretical model for lean and sustainable change (shown in Figure 4). The study sought to answer the calls for greater research into linkages between lean and sustainable operations (e.g. Mollenkopf *et al.*, 2010; Azevedo *et al.*, 2012) and identify the full sustainability benefits of lean operations beyond the green improvements at the workplace level that most research is

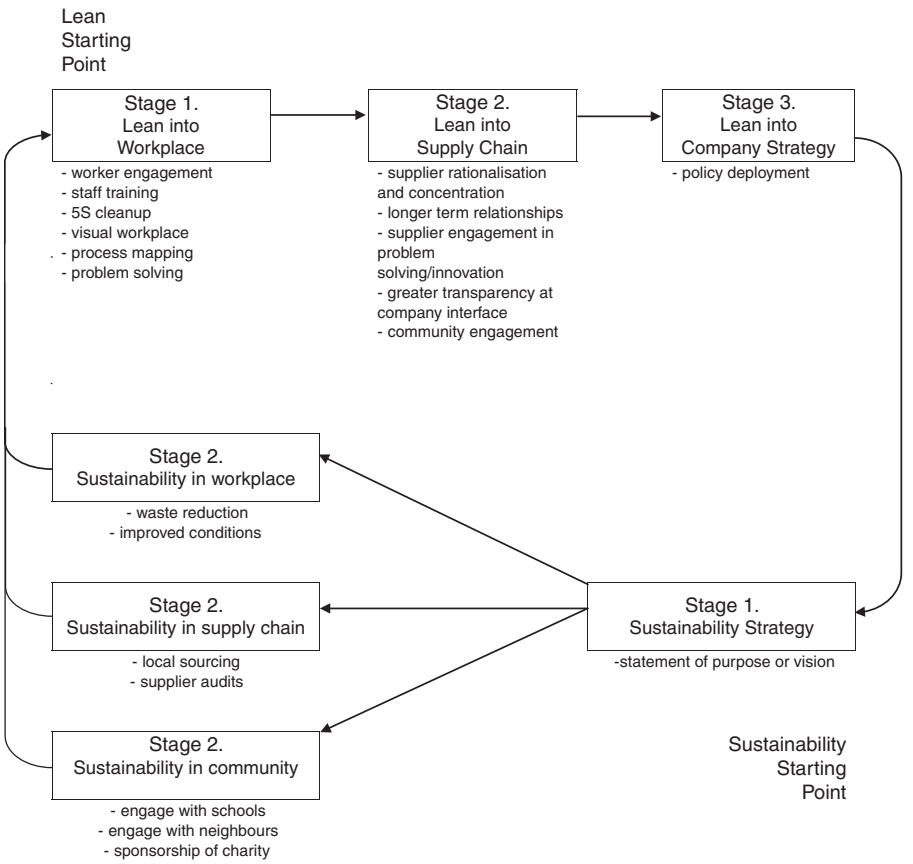

Figure 4.
Theoretical stage model for integrating lean and sustainable operations

limited to (e.g. Zhu and Sarkis, 2004; Lapinski *et al.*, 2006). In addition, we have sought to build a model that integrates both sustainability and lean in a single framework, even where each activity may be started independently. We also highlight an evolutionary pathway for the implementation of both areas, as opposed to treating each activity as dichotomously on-or-off approach.

The research clearly identifies the specific sustainability benefits of lean approaches but further seeks to add to research in this area by fully conceptualising the combined change process (shown in Figure 2). Those lean-first companies went through three clear stages of workplace- to supply chain- to strategy-change. Each stage had clear sustainability benefits and led to a company wide focus on sustainability through PD (in two cases), even if the primary outcomes of this programme were rebranding lean initiatives rather than new improvements. The companies starting with sustainability undertook a range of improvements in parallel driven from their sustainability strategy that over time created a ready made base for lean improvement, and in the case of MetalCo specifically identified production problems requiring lean solutions.

The evolution of lean and sustainability is clearly different. While there must be some (mid-level) top-down direction for lean change (often from the production manager/director), this was first focused on improving production and later supply.

Only when there were demonstrable achievements from these activities could the top levels of the organisation be engaged in changing the overall strategic process to adopt policy deployment. A process of evolution was observed from easy-wins in the work-place to the harder task of changing a supply chain through to the ultimate challenge of altering the entire strategy process of the company. Conversely the process of sustainability adoption focused on strategy first. The strategic element of sustainability differed to the lean approach – where the lean approach focused on both content (leanness) and process (policy deployment) of strategy, sustainability focused only on content (adopt sustainable working). The top-down dictate to all areas of the company at the start of the sustainability process also made it possible for each area (workplace, supply chain, community) to be addressed at once as each were the responsibility of different functions working in parallel.

This model is a useful guide for the academic community, as well as managers, to understand the change or improvement processes taking place as companies move toward lean or sustainable operations. It is also useful (when combined with the tables above) to identify explicitly the cross-over of tools/techniques from one approach to the other, demonstrating the mutual compatibility of both approaches. Past research has only hinted on this compatibility. For instance, while Franchetti *et al.* (2009) highlight how inventory and statistical tools can support waste reduction to benefit operational and environmental agendas, others discuss the dual benefits of a positive work environment (see Corbett and Klassen, 2006; Hughes, 2012). Few, if any, past studies have provided a comprehensive analysis of all costs and benefits and integrated them in a single model. This model is useful in resolving many of the calls of past researchers to address this issue:

> Although ex post there are numerous examples of how an environmental perspective has improved practice […] it is near impossible to predict ex ante precisely where these benefits will emerge (Corbett and Klassen, 2006, p. 6).

The model also touches on the issues raised by Florida (1996) regarding the common basis for lean and green improvement; where he suggests that firms innovative in one approach will naturally be led to the other, this research provides new explicit evidence in support of it.

The mutually supportive nature of lean-sustainable improvement questions the trade-off mentality that many identify in sustainability. The model here is concurrent with Schumpeter's view of creative-responses to overcome traditional tradeoffs to redefine competitive bases. Certainly each company here saw clear mutual benefit for lean and sustainability in every area of operation. Failure to understand the linkages between investment in sustainability and broader improvement are dangerous as they can lead management to see sustainability as a cost, which in an economic recession can ill be afforded (Klassen and McLaughlin, 1993; Corbett and Klassen, 2006). Past research by Azevedo *et al.* (2011) found organisational resistance to ISO 14001 where companies were forced to adopt it, even where the companies agreed with general improvement in sustainability performance. The ability to better "sell" the benefits of all sustainability activities, including international standards, can be a powerful motivator to gain co-operation. The research here supports this aim by demonstrating that investment in sustainability can provide a foundation for large cost, quality, and productivity improvements through lean improvement, and that those companies already completing sustainable programmes are able to realise these benefits faster than companies starting lean without this experience.

Conclusion

This paper reports on a multi-case investigation of how lean operations demonstrate significant sustainability benefits. From this study we also highlight how sustainability practices support a range of lean transformation goals.

Where previous studies of lean operations have limited their investigation to a study of environmental benefits at the workplace level, this paper identified strategic, supply chain and workplace activities that implemented for lean improvement offer sustainability improvement either explicitly or implicitly. The conceptual foundation of the paper outlined that a range of potential benefits may accrue from lean implementation. These were all validated by the empirical study. Further, the process of lean or sustainable change was integrated into a theoretical model to capture the holistic change process.

(i) Managerial implications

For the management community there are many clear implications of this study. The stage model provides a tool to benchmark performance and aid long term planning within the company. The mutuality of lean and sustainability identified here can also provide the manager with support for over-coming resistance to either approach at multiple levels. Workers fearful of their jobs from lean change can be reassured with the positive community and workplace engagement it brings, while those sceptical of the benefits of sustainability can be sold on its advantages by framing sustainability programmes as a precursor to lean investment and cost saving or quality improvement. Within the paper a full range of tools and processes are outlined, as well as the marketable benefits of each. This can provide the company with a clear starting point in their improvement across lean and sustainability agendas.

(ii) Limitations and future research

While the change cases here are focused on the positive achievements of each company it should be noted that transformation was not necessarily always smooth: CosmeticCo faced issues in trying to convince large suppliers to alter packaging to meet their handling/sustainability objectives; FurnitureCo observed that too much engagement can lead to a lack of clear leadership for process improvement with too much debating taking place; MetalCo struggled with the focus on Toyota and cars in lean change and how to convince sceptics of the relevance for them; and workers in several companies were fearful of how changes would affect their jobs. Any change programme will lead to resistance but each case company consistently worked toward over-coming barriers to realise improvement on both lean and sustainability fronts. The purpose of this paper was not to investigate dealing with resistance to change as this topic has been extensively covered elsewhere; however, a full analysis of how resistance feeds into the improvement approach would be a meaningful extension of the integrative model. Application and testing of this model beyond the context of the five case companies would also be of interest – extending from manufacturing to look at other stages of the supply chain or forward to retail and service businesses to investigate how improvement occurs. More research is also needed on the policy deployment process, an area of lean research that has been scantily covered since the 1980s with none identifying the role it plays in sustainability, yet here was crucial in integrated workplace/supply change and driving forward company performance.

As the global community in both business and consumer markets see quality and sustainability as order qualifiers, tackling operations and sustainability improvement will become a must-do activity for organisations.

References

Acur, N. and Englyst, L. (2006), "Assessment of strategy formulation: how to ensure quality in process and outcome", *International Journal of Operations and Production Management*, Vol. 26 Nos 1/2, pp. 69-93.

Akao, Y. (1989), *Hoshin Kanri*, Productivity Press, Portland.

Anselmsson, J. and Johansson, U. (2007), "Corporate social responsibility and the positioning of grocery brands", *Int. J of Retail and Distribution Management*, Vol. 35 No. 10, pp. 835-586.

Azevedo, S., Carvalho, H. and Cruz-Machado, V. (2011), "The influence of green practices on supply chain performance", *Transportation Research Part E*, Vol. 47 No. 6, pp. 850-871.

Azevedo, S., Carvalho, H., Duarte, S. and Cruz-Machado, V. (2012), "Influence of green and lean upstream supply chain management practices", *IEEE Transactions on Engineering Management*, Vol. 59 No. 4, pp. 753-765.

Bicheno, J. and Catherwood, P. (2005), *Six Sigma and the Quality Toolbox*, Picsie Books, Bucks.

Brammer, S. and Walker, H. (2011), "An international study of sustainable procurement", *International Journal of Operations and Production Management*, Vol. 31 No. 4, pp. 452-476.

Buysse, K. and Verbeke, A. (2003), "Proactive environmental strategies: a stakeholder management perspective", *Strategic Management J*, Vol. 24 No. 5, pp. 453-470.

Cabral, I., Grilo, A. and Cruz-Machado, V. (2012), "A decision making model for lean, agile, resilient and green supply chain management", *International Journal of Production Research*, Vol. 50 No. 17, pp. 4830-4845.

Carter, C., Auskalnis, R. and Ketchum, C. (1999), "Purchasing from minority business enterprises", *The J of Supply Chain Management*, Vol. 35 No. 4, pp. 28-32.

Carvalho, H., Azevedo, S., Duarte, S. and Cruz-Machado, V. (2011), "Green and lean paradigms influence on sustainable development of manufacturing supply chains", *Int. J. of Green Computing*, Vol. 2 No. 2, pp. 45-62.

Clargo, M. (2002), *Managing by Design: Using QFD to Transform Management Practice*, Tesseracts, London.

Cooke, M.W., Williams, S.J. and Esain, A., (2010), "Lean email: applying 5S to emails", *British Medical Journal*, available at: http://careers.bmj.com/careers/advice/view-article.html?id=20000682.

Corbett, C. and Klassen, R. (2006), "Extending the horizons: environmental excellence as key to improving operations", *Manufacturing and Service Operations Management*, Vol. 8 No. 1, pp. 5-22.

Easterby-Smith, M., Thorpe R. and Lowe A. (1997), *Management Research an Introduction*, Sage Publications, London.

Eisenhardt, K. (1989), "Building theories from case study research", *Academy of Management Review*, Vol. 14 No. 4, pp. 532-550.

Farish, M. (2009), "Plants that are green: Toyota's lean manufacturing", *Engineering and Technology*, Vol. 4 No. 3, pp. 68-69.

Florida, R. (1996), "Lean and green", *California Management Review*, Vol. 39 No. 1, pp. 80-105.

Florida, R. and Davison, D. (2001), "Gaining from green management: environmental management systems inside and outside the factory", *California Management Rev*,

Vol. 43 No. 3, pp. 64-85, available at: http://connection.ebscohost.com/c/articles/4685556/gaining-from-green-management-environmental-management-systems-inside-outside-factory

Franchetti, M., Bedal, K., Ulloa, J. and Grodek, S. (2009), "Lean and green: industrial engineering methods are natural stepping stones to green engineering", *Industrial Engineer*, Vol. 41 No. 9, pp. 24-29.

Frosch, R. (1994), "Industrial ecology: minimizing the impact of industrial waste", *Physics Today*, Vol. 47 No. 11, pp. 63-68.

Geffen, C. and Rothenberg, S. (2000), "Suppliers and environmental innovation: the automotive paint process", *International Journal of Operations and Production Management*, Vol. 20 No. 2, pp. 166-186.

George, M., Rowlands, D. and Kastle, B. (2003), *What is Lean Six Sigma?* McGraw Hill, New York, NY.

Graafland, J.J., Eijffinger, S.C.W. and Smid, H. (2004), "Benchmarking of corporate social responsibility: methodological problems and robustness", *J of Business Ethics*, Vol. 53 Nos 1/2, pp. 137-152.

Green, J., Lee, J. and Kozman, T. (2010), "Managing lean manufacturing in material handling operations", *International Journal of Production Research*, Vol. 48 No. 10, pp. 2975-2993.

Grief, M. (1991), *The Visual Factory: Building Participation Through Shared Information*, Productivity Press, Portland.

Gummesson, E. (1991), *Qualitative Research Methods in Management Research*, Sage, London.

Hines, P. (2011), "Lean and green", *Operations Management*, Vol. 37 No. 1, pp. 18-21.

Hines, P., Holweg, M. and Rich, N. (2004), "Learning to evolve: a review of contemporary lean thinking", *International Journal of Operations and Production Management*, Vol. 24 No. 10, pp. 994-1011.

Hirando, H. (1995), *Five Pillars of the Visual Workplace*, Productivity Press, Portland.

Ho, S. (2010a), "Integrated lean TQM model for global sustainability and competitiveness", *TQM Journal*, Vol. 22 No. 2, pp. 143-158.

Ho, S. (2010b), "Integrated lean TQM model for global sustainable development", *TQM Journal*, Vol. 22 No. 6, pp. 583-593.

Holstein, J.A. and Gubrium, J.F. (1995), *The Active Interview, Qualitative Research Methods Series*, Vol. 37, Sage Publications, Thousand Oaks, CA.

Hughes, M. (2012), "A lean, green, school bus making machine", *Industrial Engineer*, Vol. 44 No. 5, pp. 28-33.

Ishikawa, K. (1985), *What is Total Quality Control? The Japanese Way*, Prentice Hall, London.

Jeffers, P. (2010), "Embracing sustainability: information technology and the strategic leveraging of operations in third-party logistics", *International Journal of Operations and Production Management*, Vol. 30 No. 3, pp. 260-287.

Jenkins, H. (2006), "Small business champions for corporate social responsibility", *J of Business Ethics*, Vol. 67 No. 3, pp. 241-256.

Kainuma, Y. and Tawara, N. (2006), "A multiple attribute utility theory approach to lean and green supply chain management", *International Journal of Production Economics*, Vol. 101 No. 1, pp. 99-108.

King, A.A. and Lenox, M.J. (2001), "Lean and green? An empirical examination of the relationship between lean production and environmental performance", *Production Operations Management*, Vol. 10 No. 3, pp. 244-256.

Kitazawa, S. and Sarkis, J. (2000), "The relationship between ISO 14001 and continuous source reduction programs", *International Journal of Operations and Production Management*, Vol. 20 No. 2, pp. 225-248.

Klassen, R.D. (2000), "Just-in-time manufacturing and pollution prevention generate mutual benefits in the furniture industry", *Interfaces*, Vol. 30 No. 3, pp. 95-106.

Klassen, R.D. (2001), "Plant-level environmental management orientation: the influence of management views and plant characteristics", *Production and Operations Management*, Vol. 10 No. 3, pp. 257-275.

Klassen, R.D. and McLaughlin, C.P. (1993), "TQM and environmental excellence in manufacturing", *Indust. Management Data Systems*, Vol. 93 No. 6, pp. 14-22.

Kleindorfer, P., Singhal, K. and van Wassenhove, L. (2005), "Sustainable operations management", *Production and Operations Management*, Vol. 14 No. 4, pp. 482-492.

Kok, P., Wiele, T., McKenna, R. and Brown, A. (2001), "A corporate social responsibility audit with a quality management framework", *J of Business Ethics*, Vol. 31 No. 4, pp. 285-297.

Kurogane, K. (1993), *Cross Functional Management: Principles and Practical Applications*, Asian Productivity Organization, Tokyo.

Lamming, R. (1993), *Beyond Partnership: Strategies for Innovation and Lean Supply*, Prentice Hall, New York, NY.

Lamming, R. (1996), "Squaring lean supply with supply chain management", *International Journal of Operations and Production Management*, Vol. 16 No. 2, pp. 183-196.

Lapinski, A., Horman, M. and Riley, D. (2006), "Lean processes for sustainable project delivery", *Journal of Construction Engineering and Management*, Vol. 132 No. 10, pp. 1083-1091.

Lapré, M., Mukherjee, A. and van Wassenhove, L. (2000), "Behind the learning curve: linking learning activities to waste reduction", *Management Sci*, Vol. 46 No. 5, pp. 597-611.

Lee, K. and Shin, D. (2010), "Consumers responses to CSR activities", *Public Relations Review*, Vol. 36 No. 2, pp. 193-195.

McCarthy, D. and Rich, N. (2004), *Lean TPM: A Blueprint for Change*, Butterworth-Heinemann, London.

Macdonald, M.E. (1991), "British report says JIT harms the environment", *Traffic Management*, Vol. 30 No. 9, pp. 21-22.

MacDuffie, J. (1995), "Human resource bundles and manufacturing performance: organizational logic and flexible production systems in the world auto industry", *Industrial and Labor Relations Review*, Vol. 48 No. 2, pp. 197-221.

Maignan, I. and Ferrell, O.C. (2000), "Measuring corporate citizenship in two countries", *J of Business Ethics*, Vol. 23 No. 3, pp. 283-297.

Maloni, M. and Brown, M. (2006), "Corporate social responsibility in the supply chain", *J of Business Ethics*, Vol. 68 No. 1, pp. 35-52.

Meijer, M. and Schuyt, T. (2005), "Corporate social performance as a bottom line for consumers", *Business and Society*, Vol. 44 No. 4, pp. 442-461.

Merli, G. (1990). *Total Manufacturing Management*, Productivity Press, Portland.

Miller, C. and Sarder, M. (2012), "Public works policy implications of sustainable reverse logistics operations", *Public Works Management and Policy*, Vol. 17 No. 1, pp. 68-82, available at: http://pwm.sagepub.com/content/17/1/68.abstract

Mingers, J. (2001), "Combining IS research methods: towards a pluralist methodology", *Information Systems Research*, Vol. 12 No. 3, pp. 240-259.

Mollenkopf, D., Stolze, H., Tate, W. and Ueltschy, M. (2010), "Green, lean, and global supply chains", *International Journal of Physical Distribution and Logistics Management*, Vol. 40 Nos 1/2, pp. 14-41.

Moyano-Fuentes, J., Sacristán-Díaz, M. and Martinez-Jurado, P. (2012), "Cooperation in the supply chain and lean production adoption: evidence from the Spanish automotive industry", *International Journal of Operations and Production Management*, Vol. 32 No. 9, pp. 1075-1096.

Nishiguichi, T. (1994), *Strategic Industrial Purchasing: The Japanese Advantage*, Oxford University Press, Oxford.

Oakland, J. (1989), *Total Quality Management*, Heinemann, London.

Oglethorpe, D. and Heron, G. (2010), "Sensible operational choices for the climate change agenda", *International Journal of Logistics Management*, Vol. 21 No. 3, pp. 538-557.

Ohno, T. (1988), *The Toyota Production System: Beyond Large-Scale Production*, Productivity Press, Portland.

Osada, T. (1991), *The Five S's Keys to a Total Quality Environment*, APO, Tokyo.

Panapanaan, V., Linnanen, L., Karvonen, M. and Phan, V. (2003), "Roadmapping corporate social responsibility in Finnish companies", *J of Business Ethics*, Vol. 44 Nos 2/3, pp. 133-148.

Pascale, R. and Athos, A. (1981), *The Art of Japanese Management*, Penguin, New York, NY.

Peattie, K. (1997), *Environmental Marketing Management: Meeting the Green Challenge*, Pitman Publishing, London.

Piercy, N. (2008), *Market-led Strategic Change*, Butterworth-Heinemann, Oxford.

Piercy, N. and Rich, N. (2009), "Lean transformation in the call service centre", *International Journal of Operations and Production Management*, Vol. 29 No. 1, pp. 54-76.

Pil, F. and Rothenberg, S. (2003), "Environmental performance as a driver of superior quality", *Production Oper. Management*, Vol. 12 No. 3, pp. 404-415.

Porter, M. (1991), "America's green strategy", *Scientific American*, Vol. 264 No. 4, p. 168.

Porter, M. and van der Linde, C. (1995), "Green and competitive: ending the stalemate", *Harvard Bus. Rev.*, Vol. 73 No. 5, pp. 120-134.

Prasad, M. and Sutharasan, M. (2012), "Integrated of lean principles with sustainable manufacturing", *Int. J. of Lean Thinking*, Vol. 3 No. 1, p. 102.

Rich, N., Bateman, N., Esain, A., Massey, L. and Samuel, D. (2006), *Lean Evolution*, Cambridge University Press, Cambridge.

Romm, J.J. (1999), *Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions*, Island Press, Washington, DC.

Rothenberg, S. (2003), "Knowledge content and worker participation in environmental management at NUMMI", *Journal of Management Studies*, Vol. 40 No. 7, pp. 1783-1802.

Rothenberg, S., Pil, F. and Maxwell, J. (2001), "Lean, green, and the quest for superior environmental performance", *Production Oper. Management*, Vol. 10 No. 3, pp. 228-243, available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1937-5956.2001.tb00372.x/abstract;jsessionid=B76E962E1282B4EBCB1A0C1EAE854791.f02t03

Sandras, W. (1989), *Just in Time, Making it Happen*, Oliver Wright, Essex, VT.

Sarkis, J. (1995), "Supply chain management and environmentally conscious design and manufacturing", *International Journal of Environmentally Conscious Design and Manufacturing*, Vol. 4 No. 2, pp. 43-52.

Schroeder, R. and Flynn, B. (2001), *High Performance Manufacturing*, Wiley, New York, NY.

Simpson, D. and Power, D. (2005), "Use the supply relationship to develop lean and green suppliers", *Supply Chain Management: An International Journal*, Vol. 10 No. 1, pp. 60-68.

Slack, N. (1991), *The Manufacturing Advantage*, Mercury Press, London.

Sroufe, R.S. (2003), "Effects of environmental management systems on environmental management practices and operations", *Production and Operations Management*, Vol. 12 No. 3, pp. 416-431.

Storey, J. (1994), *New Wave Manufacturing Practice: Organisational and Human Resource Management Dimension*, PCP, London.

Stuart, I., McCutcheon, D., Handfield, R., McLachlin, R. and Samson, D. (2002), "Effective case research in operations management: a process perspective", *Journal of Operations Management*, Vol. 20 No. 5, pp. 419-433.

Székelly, F. and Knirsch, M. (2005), "Responsible leadership and corporate social responsibility", *European Management Journal*, Vol. 23 No. 6, pp. 628-647.

Taubitz, M. (2010), "*How Safety Fits with Sustainability, Occupational Health and Safety*", Online Edition, September, available at: http://ohsonline.com/articles/2010/09/01/how-safety-fits-with-sustainability.aspx

Toyota (2011), "Toyota annual report", available at: www.toyota-global.com/investors/ir_library/annual/pdf/2011/ (accessed Summer 2012).

Turker, D. (2009), "Measuring corporate social responsibility: a scale development study", *Journal of Business Ethics*, Vol. 85 No. 4, pp. 411-427.

Voss, C., Tsikriktsis, N. and Frohlich, M. (2002), "Case research in operations management", *International Journal of Operations and Production Management*, Vol. 22 No. 2, pp. 195-219.

Wagner, T., Bicen, P. and Hall, Z. (2008), "The dark side of retailing: towards a scale of corporate social irresponsibility", *Int.J of Retail and Distribution Management*, Vol. 36, No. 2, pp. 124-142.

Wan, H. and Chen, F. (2008), "A leanness measure of manufacturing systems for quantifying impacts of lean initiatives", *International Journal of Production Research*, Vol. 46 No. 23, pp. 6567-6584.

Waring, T. and Wainwright, D. (2002), "Communicating the complexity of computer-integrated operations", *International Journal of Operations and Production Management*, Vol. 22 No. 4, pp. 394-412, available at: www.emeraldinsight.com/doi/full/10.1108/01443570210420403

Womack, J. and Jones, D. (1996), *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, 2nd ed., Free Press, New York, NY.

Womack, J. and Jones, D. (2005), *Lean Solutions: How Companies and Customers Can Create Value and Wealth Together*, Free Press, New York, NY.

Womack, J., Jones, D. and Roos, D. (1990), *The Machine that Changed the World*, Simon and Schuster, London.

Yin, R.K. (2008), *Case Study Research: Design and Methods*, 4th ed., Sage Publications, Thousand Oaks, CA.

Zhu, Q. and Sarkis, J. (2004), "Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises", *Journal of Operations Management*, Vol. 22 No. 3, pp. 265-289.

Zokaei, K., Lovins, H., Wood, A. and Hines, P. (2013), *Creating a Lean and Green Business System: Techniques for Improving Profits and Sustainability*, CRC Press, Boca Raton, FL.

Further reading

Larson, A., Teisberg, E. and Johnson, R. (2000), "Sustainable business: opportunity and value creation", *Interfaces*, Vol. 30 No. 3, pp. 1-12.

Parnaby, J. (1986), "The design of competitive manufacturing systems", *International Journal of Technology Management*, Vol. 1 No. 3, pp. 385-397.

Piercy, N. and Brammer, S. (2012), "A complete definition of corporate social responsibility and sustainability", British Academy Report.

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