Cranfield University

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Exploration of the integration of Lean and environmental improvement

School of Applied Science

PhD Thesis
2009/10

Prof. S. Evans
September, 2009

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This thesis is submitted in partial fulfilment of the requirements for the Degree of PhD

Abstract

With increasing awareness of the environmental damage that is occurring as a result of human activities, there are also increasing pressures on manufacturing companies to reduce environmental impacts. Many environmental impact reduction methods contain some element of waste reduction, which is also the focus of Lean manufacturing, although their definitions of waste differ somewhat. The aim of this research was to investigate the synergies and similarities between Lean manufacturing and environmental impact reduction in manufacturing, with a strong focus on practical implications.

The research was carried out in three stages: a review of the relevant literature, an exploration stage which consisted of semi-structured interviews with ten companies, and action research studies with two companies, investigating company reactions to the introduction of environmental impact reduction measures into their Lean implementation, via adapted tools designed using data from the literature review and exploration stage.

Findings from all the research stages were analysed and synthesised, producing a total of 54 findings (including answers to research questions, notes for practitioners, and suggestions for future work) across 12 themes.

The research confirmed that some environmental improvement occurs as a side effect of Lean implementations; compared Lean and environmental wastes; looked at potential benefits of mapping for environmental improvement within Lean implementations; found that Lean can be used as a framework for other changes, including environmental improvement; identified opportunities for adoption or adaptation of particular Lean tools for environmental impact reduction; identified new ways in which Lean acts as a foundation for change; showed common uses for goals and measures; found that workforce involvement was an important factor, as was education and training; identified some factors for acceptance and adoption; discussed the effectiveness of integrated implementation; and discussed the benefits of holistic integration of Lean and environmental improvement.

Acknowledgements

I would like to thank all of the company respondents who so generously contributed their time and knowledge. Particular thanks to all those involved in this project at “company B” and “company H”, for hosting the action research stages.

A million thanks to Professor Steve Evans for supervising this project.

Thanks to Salwa and Carol, for all those discussions about methodology and research.

My family have been a tremendous source of moral support during the project – especially, thanks to Marion, Graham, Kate and Steve.

Finally, thanks to Rich, for all your support and reassurance; for being a fantastic sounding board for ideas; and not least, for cut-price board and lodgings for the last year!

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Glossary

5S Five stages in a plan of work to make a workplace suitable for Lean production and visual control. The name of each stage begins with S in Japanese and the names have been translated into 5 words in English that also begin with S. Seiri – sort out (get rid of all unwanted, unused or broken items from the area), Seiton – Set in order (put the remaining items in sensible locations, and mark them), Seiso – sweep and shine (make sure the area is clean, and look for anything that is wrong or out of place), Seiketsu – schedule (devise a cleaning and tidying schedule to maintain and improve the current standard), Shitsuke – stick to it (keep going! Make sure the standard improves).

Action research Action research means that the researcher is an active participant in the research setting and may instigate change, is present while key parts of the process being researched are occurring, and observes what happens (Eden and Huxham, 1996).

BB Black belt. Someone who has completed advanced training in Lean. The black belts are the disseminators and trainers and main organisers of Lean within Company B

Cellular manufacturing All the work stations for one family of products are arranged in order in one area or cell, enabling better flow of the processes, reducing travelling within the factory and making one-piece-flow easier

CSPS Company specific production system – a company's own, branded version of Lean which may be adapted to the company's requirements

CSPSC Company specific production system champion

CSPST Company Specific Production System Trainer. Visiting company B from the parent company's headquarters, responsible for overseeing training and the deployment of the new CSPS

EHSM Environment, health and safety manager

EHSR. A member of the EHS department, with responsibility for training staff in the company's EHS policies and campaigns.

Environmental impacts and aspects register A company's list of the environmental impacts associated with their activities (those that occur during normal operations and those that might be caused by accidents or emergencies) and the likelihood, frequency and severity of these impacts.

Goal cascade top-level goals are broken down into a number of levels of sub-goals appropriate to each level and role within the company, in such a way that fulfilling the sub-goals would lead ultimately to fulfilling the overall goals

Heijunka (levelling) create a regular sequence of production of different products where possible to meet known regular patterns of demand

Integrated implementation Implementation of Lean where environmental impact reduction is deliberately integrated

JIT Just in time – closely related to pull systems. Minimising inventories and work-in-progress, sycnchronisation of processes

Kaikaku (sometimes known as Kaizen blitz) Large "shake-up" changes such as a shift to visual control, changing to cellular manufacture, implementing one-piece flow…

Kaizen (Continuous Improvement) smaller steps of improvement, often suggested by the people working on a line or cell (as opposed to management or the improvement team)

Kanban A pull-system for components and sub-assemblies, setting maximum and minimum limits for the inventory, visually

Lean A strategy for doing business efficiently, with the workforce involved in making improvements continuously, making exactly what the customer wants when they want it (and not before), and minimising waste of all kinds.

MD Managing director

Milk run Ties in with JIT – vehicles delivering or collecting goods are routed to make multiple small drops/pick-ups more regularly, and preferably using all space on the vehicle, to minimise inventory and transport mudas

Muda the Lean term for wastes

OM Operations manager

PMD Previous managing director

Poka-yoke "Mistake proofing" **-** designing tools etc. in such a way that mistakes are impossible (e.g. making a jig so that it is impossible to put a part into it the wrong way around)

Pollution prevention Pollution is prevented at source rather than emissions being treated at the end of the pipe.

Pull / push In a pull system, customer orders "Pull" work through the process, in a push system, work is "pushed" through in batches to build up stock, and is then held pending orders

Rightsizing Making equipment the right size for the flow of work, so that batch flow is not necessary

Root cause analysis (five whys) If you deal with the root cause of a problem, it will never come back. Go to gemba (wherever the problem is occurring) and keep asking "why" until the root cause is revealed (typically, it is necessary to go down 5 levels of "why" to get to the root cause)

Single piece flow (as opposed to batch-and-queue) Products are made one by one instead of in batches. Reduces inventories, reworking and scrap (because mistakes are caught after only a few products have been made wrongly rather than a whole batch), handling, errors in identification…

SMED (Single-minute exchange of dies) Reducing time required to make any changes to equipment in order to switch from producing one product to another – allows production by a pull system and one-piece flow instead of batch flow.

Smoothing Planning production levels so that there is the same amount of work every day and everyone is always busy but all orders leave on time

Takt time Available production time divided by number of products demanded by customer

TPM (Total Productive Maintenance) Planned maintenance schedules are devised to keep all equipment running 100% of the time

Turn-back analysis Analysis of how often work is turned back to an earlier stage of the process for reworking

Value / muda As discussed above

Value stream mapping Identifying families of products, then for each family identifying each step in their manufacturing process and highlighting which steps are not adding value and thus constitute muda in one of the categories (see table above)

Visual control All controls and measures (eg flow of work, order progress, stock levels, call for replenishment of stock) are done visually, using control boards (including Andon boards), coloured cards and markers, kanban/two-bin etc.

1 Introduction

Overview

The introduction chapter provides some background to the research, then explains the research aims and questions, gives an overview of the research and explains the thesis structure.

1.1 Introduction and background to the research

Perhaps many generations feel that they are living in interesting times, but those concerned about environmental impact certainly have cause to feel that today. There is a persistent flow of news about the impacts of our behaviour and the possible future effects of those impacts, but also of a gathering intention to act among private individuals and world leaders.

This research focuses on UK manufacturing businesses and for them there are a number of reasons to act to reduce their environmental impacts - for example, customers, whether these are individual consumers or other businesses, are beginning to be concerned about sustainability and environmental credentials, and companies are concerned about the effect on their reputation that any report of “bad environmental behaviour” might have; there is environmental legislation with which they are obliged to ensure compliance; there are environmental accreditation schemes which they may attain; plans are afoot to introduce carbon trading; and interlinked with environmental impacts are the costs and predicted availability of energy, fuel, materials and waste disposal, which are driving them to rethink their behaviour in ways that can also reduce impacts (Dow Corning, 2007; EEF & Envirowise, 2008).

There are very many approaches to reducing environmental impacts, but what they often have in common is a consideration of ways to reduce waste. This is the factor that initiated this research, because manufacturing companies have been talking about waste reduction for some years in a slightly different context – that of Lean manufacturing.

Lean manufacturing started out as the Toyota Production System, which began around 1949 and is continually being improved. Lean manufacturing is Toyota’s radical modification and improvement on manufacturing strategies that were in use at the time. Through a planned system of activities, a Lean implementation defines value as the customer sees it, maps the way that a manufacturer adds value to its products (often with a technique called value stream mapping), then provides tools for identifying and removing all kinds of waste. In Lean terms the definition of waste, known by the Japanese term *muda*, is important (for more detail see section 2.2.2).

The perception that there was an element of waste reduction in both Lean and environmental improvement prompted some questions. Are there more points of similarity between Lean and environmental improvement? If there are, could they be used to help companies make environmental improvements? How would companies react to this idea?

These questions formed the basis of the research aims and research questions.

1.2 Research aims and Research questions

Research aims

The first aim of the research is to investigate what Lean and environmental improvement have in common.

Based on this investigation, the next research aim is develop a toolset that can be used as a basis for action research in companies. In this action research the aim will be to understand more about how companies use, and react to, the toolset and the idea of integrating Lean and environmental improvement, and to investigate the effects of implementation.

Research questions

The research questions are –

- Research question 1 - If there are synergies and similarities between Lean and environmental improvement, what are they?
- Research question 2 - How can the synergies between Lean and environmental improvement be used to inform integrated implementation?
- Research question 3 - What happens when Lean and environmental improvements are made together?

1.3 Thesis aims

The aim of this thesis is to explain the contribution to knowledge and findings from the research, and how the findings were generated; and to provide evidence that the research is novel, valid, reasonable and clear.

1.4 Research structure

Chapter 3 explains the methodology choices for this research in more detail.

As an overview, the research was conducted in stages including the literature review, followed by semi-structured interviews with ten UK manufacturing companies' Lean and environmental representatives. On the basis of these two stages, a tool set was built, which was used as the basis for long-term action research case studies with two companies, before final analysis and synthesis of data.

1.5 Thesis overview

Chapter 2 of the thesis provides a comprehensive review of other published research on the combination of environmental or sustainability improvement with Lean manufacturing.

The chapter begins by introducing Lean, sustainability and environmental impact.

Next, the method used to carry out a thorough search for relevant literature is explained.

The first part of the main literature review is presented in five sections relating to the nature of any synergies between Lean manufacturing and environmental or sustainability improvements, corresponding to the main themes identified in the literature.

Next the material discussing the potential for integrating Lean and environmental or sustainable thinking and improvement activities is reviewed. The findings from the literature on the differences and hostilities between the two concepts, the inhibitors that make it hard to integrate them, and the progress towards integration are presented in turn.

The last sections of the chapter discuss gaps in the existing literature that this research might be targeted to fill.

Chapter 3 of the thesis discusses the methodology chosen for this research.

The chapter begins with an introduction to methodology design, then gives an overview of the options considered, followed by an explanation of which of these options were chosen and why they were deemed suitable. The next sections discuss validity, reasonableness and bias avoidance. Finally, the design for this research and the bias avoidance methods chosen are set out.

<u>Chapter 4</u> of the thesis explains how the exploration stage interviews were carried out (including interview questions / design) and presents the interview findings.

The chapter begins by explaining the interview method, then discusses company selection criteria and methods and the profiles of companies that took part in the interviews.

The main body of the chapter presents the findings from the interviews organised by themes that emerged during analysis of the interview responses.

The key findings are then summarised in a separate section, grouped together according to the research question whose answers they inform. Negative cases are discussed and presented.

<u>Chapter 5</u> of the thesis explains the tool and case study design. The chapter begins by providing a recapping of the findings from previous research stages that inform the tool and case study design. The tools are then described and explained, then the design of the case study method and how it fits around the tools is explained.

<u>Chapter 6</u> of the thesis explains how the first case study was carried out and presents the findings from it.

The chapter explains the aims of the chapter and of the case study, then gives some background information about the company and the people whose input was most important during the case study. The chapter then goes on to outline the action research structure used in the case study.

The main part of the chapter explains each stage of the case study, based on the implementation plan which can be seen to be divided roughly into three sections; planning, implementation, and feedback and discussion of next steps.

The chapter then goes on to deal with the “negative cases” (data that goes against the findings developing in the rest of the chapter) and considers what might be applicable outside the case study company.

Chapter 7 of the thesis explains how the second case study was carried out and presents the findings from it. The chapter follows the structure of Chapter 6 above.

Chapter 8 The final synthesis chapter summarises all the key findings from the three research phases (literature review, interviews and case studies), organised by themes.

Chapter 9 The Conclusions chapter begins by summarising the answers to research questions, then discusses strengths and weaknesses and potential sources of bias in the research and their avoidance. The chapter goes on to discuss the contribution to knowledge, provides notes for practitioners and discusses possible future work suggested by this research.

1.6 Conclusions

This chapter has explained how the research interest and aims evolved from current concerns about environmental impacts and an initial perception of potential synergy between environmental impact and Lean manufacturing in that both are concerned in some way with waste. Section 1.4 sets out the research structure and section 1.5 gives an overview of the thesis; the research aims and questions were set out in section 1.3.

2 Literature Review

Chapter overview

This chapter provides a comprehensive review of other published research on the combination of environmental or sustainability improvement with Lean manufacturing.

The chapter begins by introducing Lean, sustainability and environmental impact.

Next, the method used to carry out a thorough search for relevant literature is explained.

The first part of the main literature review is presented in five sections relating to the nature of any synergies between Lean manufacturing and environmental or sustainability improvements, and corresponding to the main themes identified in the literature. These are the environmental "side-effects" of Lean (environmental benefits that were not key aims of the implementation), Lean as a way to achieve a wide range of goals which some authors suggest could include environmental goals, the main aims of Lean and how they fit with environmental or sustainability improvement, particular Lean tools and their environmental effects (current and potential) and finally how the culture and learning style typical of Lean companies can affect environmental improvements.

Next the material discussing the potential for integrating Lean and environmental or sustainable thinking and improvement activities is reviewed. The findings from the literature on the differences and hostilities between the two concepts, the inhibitors that make it hard to integrate them, and the progress towards integration are presented in turn.

Notation used

Interim findings from the literature reviews are referenced in the format [I2-x] where x is the order of appearance within this chapter.

Chapter aims

This chapter is intended to provide an introduction to the subjects of the research, to demonstrate the researcher's ability to read, understand and critically review the material found, to assess whether the findings presented are valid and reasonable, to compare and contrast the ideas that are in it and to draw out what can be of use in informing this research.

This chapter aims to show that the literature search was thorough, by describing the method used, and that the researcher has found and read appropriate material, by showing the range of papers reviewed. It will give the reader an idea of the scope, coverage and limits to expect from this thesis.

The chapter will begin to give the reader confidence on the validity of this research, because it is built on others' peer-reviewed work.

2.1 Aims of the literature review

There are many reasons for doing a literature review; the gaps in the literature identified after a comprehensive search can help to inform the selection of research questions so that the research is novel; it provides a base of information to build on and prevents duplication of effort, as the researcher knows what work and conclusions have already been published; and it helps to give the reader confidence in the validity of new research, by showing that the research is grounded in peer-reviewed work, and the researcher is competent and thorough.

A literature review begins to define the scope of the report that follows, so it shows the reader what to expect of the following report, in terms of scope and limits. This section also includes some discussion of the gaps that have been identified in the existing literature; areas that are not covered at all but might be interesting, or that are mentioned but not elaborated upon, or that seem to need more exploration.

2.2 Overview of Lean manufacturing

2.2.1 History of Lean

(Colated from Hines, Holweg, and Rich, 2004; Holweg, 2007; Spear and Bowen, 1999; Spear, 2004; Womack and Jones, 2003).

It is rather hard to say exactly when Lean "began" as it is essentially a combining of several threads of ideas. However, histories of Lean usually begin with the trip made by Eiji Toyoda, then newly-appointed managing director of Toyota's manufacturing business, to America in 1950 to learn from Deming, Ford and other American manufacturing experts of the time.

Toyota needed to become more efficient as sales in post-war Japan had slumped, leading to increasing (expensive) inventories and unrest in the labour force. However, their volumes were a tiny fraction of those processed by the US companies they were learning from, and so they needed to adopt the spirit rather than the letter of the mass-production techniques.

Taiichi Ohno realised that the high inventories and restriction of produce diversity inherent in these mass-production techniques would not suit Toyota; he was not an automotive expert but used his learning from the original Toyoda power loom company and his common sense to adapt the mass production techniques to suit Toyota and thus the Toyota Production System (TPS) began to evolve.

The concept of "evolution" is important in TPS (or Lean, as it is now more commonly known) as it has never stood still (Hines et al., 2004). Just as there is a focus on "Continuous Improvement" (described later) in the production system, so the system itself is continually being improved in the pursuit of perfection.

It is important in TPS to record all procedures and processes; but it seems likely that the TPS methodology might not have been described in writing until 1965, when the kanban system was extended outside the factory to Toyota's suppliers, who then had to be trained in TPS and needed manuals (Holweg, 2007). Those who have observed Toyota's workforce often note that they find it difficult to explain exactly how TPS works -

> *"Toyota instructs implicitly. They cannot tell you in words what they are doing, not even in Japanese"*
>
> (Holweg, 2007, p.423)

The various strands of TPS/Lean, and their origins, where available from the folklore of Lean's evolution, are presented in the next section.

2.2.2 Aims & Fundamentals

Small batches

Holweg (2007) labels Ohno's early version of Lean as "small-lot production" and this is still something companies pursuing Lean strive for today, although now it is more often called "single-piece flow". The aim is to make only one item at a time at each stage of manufacture, rather than each process being completed on multiple items before the whole batch is handed on to the next process ("batch and queue"). This can be used as part of the inventory reduction strategy, and also helps to maintain a steady flow of work through the plant, and to avoid wasted time if a batch of faulty components is received – because the first few items are likely to be tested before very many are built.

Waste

Holweg (2007) also states that waste reduction was a key feature of this early version of Lean, and it is still fundamental now. Waste in Lean is carefully described and classified (see Fig. A.1) and these categories are helpful prompts when looking for waste. It can be seen that the physical waste we throw in the dustbin, which is what we often mean by waste in everyday life, forms only a small part of the wastes Lean defines.

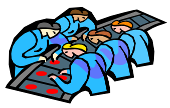
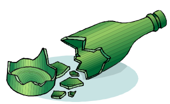
Waste (often known by its Japanese name *Muda*) can be defined as "anything the customer doesn't pay you to do", but there are some "wasteful" activities that are actually essential or useful to the business (for example time spent changing over tools between processes, measuring and testing products for quality control purposes, or administrative work to process orders) which should be minimised but not eliminated, and others that are not in any way useful and should be eliminated as soon as possible (for example, walking around to look for tools that have been misplaced).

Much of the effort in Lean is to do with finding ways to reduce waste in some way or other and many of its tools are designed to help direct this effort.

Product families

Traditionally, the physical (and mental) organisation of manufacturing is by departments – so similar machines are grouped together and run by people who are exclusively skilled in their usage. A product is made by being passed around the different departments in the correct order for the processes to be carried out to make the finished product.

Figure 2.1 – Table showing Lean's 8 wastes

Type of waste	Description
Overproduction 	Producing more than is necessary at any one time
Transport 	Unnecessary or longer than necessary transport of parts or products
Motion 	Unnecessary or longer than necessary movements of people or machines
Overprocessing 	Using time or other resources on processing steps that do not add value to the product
Waiting 	People waiting for parts from a previous operation
Inventory 	Cash is tied up in "work-in-progress" and goods built without being pulled through for a specific customer order
Defects 	Products that do not meet quality specifications require time to rework and/or scrapping of defective parts

(After Ohno, 1988)

In Lean manufacturing, the ideal is to organise everything by product families (groups of products requiring similar processes etc.). Therefore, wherever possible, all the equipment required to make each family of products will be grouped together, so that work flows through the processes and transport within the factory is reduced (Womack and Jones, 2003). Often one operator will carry out all the processes on one product, from start to end.

Value

Value is defined from the viewpoint of the ultimate customer, and is the opposite of waste – when you are not adding value, you are creating waste. Lean encourages companies to strive to maximise the percentage of their time that is spent adding value.

Value streams and value stream mapping

Lean encourages the consideration of the value stream of products – the flow of processes from extraction of materials, right through to end products. Value stream mapping maps all the steps in this value stream (extraction of raw materials, processing, transporting, forming, assembling, waiting, storage etc.) against time, helping companies to understand the value stream, estimate the percentage of the time that is adding value to the customer (one way of estimating Lean progress) and work out where wastes are occurring.

The percentage of time that is actually adding value in the majority of companies is surprisingly small. In Womack and Jones' (2003) analysis of the value stream of a can of coca-cola from raw materials to a super-store shelf, only 0.04% of the time was value-adding, with most of the non-value-adding time being taken up by waiting (i.e. where the materials or product work-in-progress were waiting to move on to the next processing step).

Inventory Reduction

Inventory generally acts as a "buffer" between processes or between the company and its customers/suppliers, against delays, variations and unexpected events. However, excessive inventory takes up room, can become obsolete, may have to be reworked to provide exactly what the customer requires, takes time and effort to put into storage, ties up money (potentially causing liquidity problems) and can hide problems in processes and procedures.

Excessive inventory of finished goods was one of the problems that spurred Toyota's initial efficiency improvement efforts (Holweg, 2007), so it is not surprising that inventory reduction is another of Lean's main features.

Just In Time (JIT)

Just in Time is the first strand of Lean that Holweg (2007) notes in his description of the foundations of Lean. He attributes its invention to Taiichi Ohno, as his response to the problems of excessive inventory and restriction of ability to customise in mass production, and Kiichiro Toyoda who Ohno quotes –

> *“In a comprehensive industry such as automobile manufacturing, the best way to work would be to have all the parts for assembly at the side of the line just in time for their user”*
>
> (Ohno, 1988, p.75)

This apparently obvious idea is actually a rather radical shift from mass production if rigorously applied, as it means that not only are bought-in parts and materials to be supplied in smaller, more frequent deliveries, but also within the factory work is undertaken in much smaller batches so that processes feed components to the next process “just in time” to be used, and ultimately products are made “just in time” to complete orders for customers – thus indicating pull systems (see below).

Pull

“Pull” manufacturing means making only what is needed to supply orders that have been received, “Just in Time” to fulfil the order (so it is clearly linked to the preceding topic). In a “pull” system, each operation will only produce parts when the succeeding operation indicates that it requires them, and in the quantities that are required. The “buffer” of inventory between processes will be minimal and tightly controlled. The Lean tools include ways to control the buffer and to pass on the order to start producing parts.

In contrast, typical mass-production manufacturing relies heavily on forecasts of sales that are likely to be placed, which are used to create manufacturing schedules which decide what each process will make and when, to build a finished goods inventory from which orders are fulfilled.

Single Minute Exchange of Dies (SMED)

A traditional mass-production system would run a process for as long as possible, building up a large inventory before breaking off to reset the process for another product. Building to schedules allows this and it was assumed that the time to change tools was invariable (and generally quite long); therefore efforts were made to set schedules to minimise changeover frequency in order to minimise wasted time. Producing “just in time” however does not allow the building up of inventory and process changeover must be quick and frequent. Toyota found that by analysing the activities within a changeover and the design of the tools, changeover times could be massively reduced (for example by simpler fixings on tools, presetting adjustments, and having tools to hand in fixed convenient locations). SMED was developed at Toyota, and introduced in 1955, by Shigeo Shingo, who Toyota has hired as a consultant.

Standardisation, perfection, participation and continuous improvement (CI)

In a Lean company, there is a standard way to do everything, and everyone is required to work to this standard practice. However, the standard way is not set in stone – quite the opposite. Continuous Improvement efforts are also required from everyone, at all levels in the company. Suggestions for improvement are made, and then checked out to see if they really do reduce waste and improve the process. If they do, then standard work will be revised to implement the improvement so that everyone now works to the new improved standard (Spear, 2004). Standardisation is seen as essential to allow improvement, so that everyone is using the best method identified so far and to ensure that unusual occurrences show up and can be rectified. The goal for Lean is "Perfection", and so once you have improved something, you go on looking for ways to improve it further.

2.2.3 How Lean is applied

Womack and Jones (2003) give five basic stages for creating a Lean organisation:

- **Understand value** – from the customer's point of view
- **Map the value stream** – how does value flow from raw material through to the final customer? What steps do not add value, are not necessary and can thus be removed?
- **Flow** – make the value-creating steps flow easily with fewer hold-ups (e.g. inventory and bottlenecks), moving towards just-in-time, cellular manufacturing, Single Minute Exchange of Dies, ...
- **Pull** – production according to customer demand rather than forecasts and making for stock
- **Perfection** – once you have gone through these steps, keep on doing them!

Lean is a strategy not an improvement process – practitioners should aim for:

> *"Producing exactly what the customer wants, exactly when (with no delay), at a fair price and with minimum waste."*
>
> (Bicheno, 2000, p.13)

Spears and Bowen explain that the important thing about TPS is not the tools and practices but the system itself, which they summarise in four rules -

> *"The tacit knowledge that underlies the Toyota Production System can be captured in four basic rules. These rules guide the design, operation, and improvement of every activity, connection, and pathway for every product and service.*
>
> *The rules are as follows:*
>
> *Rule 1: All work shall be highly specified as to content, sequence, timing, and outcome.*
>
> *Rule 2: Every customer supplier connection must be direct, and there must be an unambiguous yes-or-no*
>
> *way to send requests and receive responses.*
>
> *Rule 3; The pathway for every product and service must be simple and direct.*
>
> *Rule 4: Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organisation*
>
> *All the rules require that activities, connections, and flow paths have built-in tests to signal problems automatically. It is the continual response to problems that makes this seemingly rigid system so flexible and adaptable to changing circumstances."*

(Spear and Bowen, 1999, p.98)

2.2.4 Common Lean Tools

The following list of tools has been collected by this researcher from a variety of Lean resources (Bicheno, 2000; Hines et al., 2004; Hines and Taylor, 2000; Womack and Jones, 2003)

5S Five stages in a plan of work to make a workplace suitable for Lean production and visual control. The name of each stage begins with S in Japanese and the names have been translated into 5 words in English that also begin with S. Seiri – sort out (get rid of all unwanted, unused or broken items from the area), Seiton – Set in order (put the remaining items in sensible locations, and mark them), Seiso – sweep and shine (make sure the area is clean, and look for anything that is wrong or out of place), Seiketsu – schedule (devise a cleaning and tidying schedule to maintain and improve the current standard), Shitsuke – stick to it (keep going! Make sure the standard improves).

Cellular manufacturing All the work stations for one family of products are arranged in order in one area or cell, enabling better flow of the processes, reducing travelling within the factory and making one-piece-flow easier

Heijunka (levelling) create a regular sequence of production of different products where possible to meet known regular patterns of demand

JIT Just in time – closely related to pull systems. Minimising inventories and work-in-progress, sycnchronisation of processes

Kaikaku (sometimes known as Kaizen blitz) Large “shake-up” changes such as a shift to visual control, changing to cellular manufacture, implementing one-piece flow…

Kaizen (Continuous Improvement) smaller steps of improvement, often suggested by the people working on a line or cell (as opposed to management or the improvement team)

Kanban A pull-system for components and sub-assemblies, setting maximum and minimum limits for the inventory, visually

Milk run Ties in with JIT – vehicles delivering or collecting goods are routed to make multiple small drops/pick-ups more regularly, and preferably using all space on the vehicle, to minimise inventory and transport mudas

Poka-yoke “Mistake proofing” - designing tools etc. in such a way that mistakes are impossible (e.g. making a jig so that it is impossible to put a part into it the wrong way around)

Pull / push In a pull system, customer orders “Pull” work through the process, in a push system, work is “pushed” through in batches to build up stock, and is then held pending orders

Rightsizing Making equipment the right size for the flow of work, so that batch flow is not necessary

Root cause analysis (five whys) If you deal with the root cause of a problem, it will never come back. Go to gemba (wherever the problem is occurring) and keep asking “why” until the root cause is revealed (typically, it is necessary to go down 5 levels of “why” to get to the root cause)

Single piece flow (as opposed to batch-and-queue) Products are made one by one instead of in batches. Reduces inventories, reworking and scrap (because mistakes are caught after only a few products have been made wrongly rather than a whole batch), handling, errors in identification…

SMED (Single-minute exchange of dies) Reducing time required to make any changes to equipment in order to switch from producing one product to another – allows production by a pull system and one-piece flow instead of batch flow.

Smoothing Planning production levels so that there is the same amount of work every day and everyone is always busy but all orders leave on time

Takt time Available production time divided by number of products demanded by customer

TPM (Total Productive Maintenance) Planned maintenance schedules are devised to keep all equipment running 100% of the time

Turn-back analysis Analysis of how often work is turned back to an earlier stage of the process for reworking

Value / muda As discussed above

Value stream mapping Identifying families of products, then for each family identifying each step in their manufacturing process and highlighting which steps are not adding value and thus constitute muda in one of the categories (see table above)

Visual control All controls and measures (eg flow of work, order progress, stock levels, call for replenishment of stock) are done visually, using control boards (including Andon boards), coloured cards and markers, kanban/two-bin etc.

2.3 Overview of environmental improvement and sustainability

2.3.1 Definitions of sustainability / sustainable development

Four types of definition of sustainability are reviewed. These relate to equity, maintenance of natural capital, triple bottom line approaches and footprints.

Equity

The Brundtland report defined sustainable development as -

> *"development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs"*
>
> (World Commission on Environment and Development, 1987)

Dresner (2002) comments that this can be construed as equity between and within generations.

Forum for the future defines sustainable development as

> *"a dynamic process which enables all people to realise their potential and improve their quality of life in ways which simultaneously protect and enhance the Earth's life support systems."*
>
> (Forum for the future homepage, 2005)

Hopwood, Mellor & O'Brien (2005) quote Haughton's useful summary of the ideas of sustainable development in five principles based on equity:

- Futurity – inter-generational equity;
- Social justice – intra-generational equity;
- Transfrontier responsibility – geographical equity;
- Procedural equity – people treated openly and fairly;
- Interspecies equity – importance of biodiversity.

Maintenance of Natural Capital

Dresner (Dresner, 2002) also mentions sustainability and the link to maintenance of "natural capital", whether in absolute terms or in terms of the balance between depletion of naturally occurring capital and creation of man-made "capital" to replace it – there is a sort of continuum of views between the two.

This was a part of Herman Daly's approach (combined with the idea that growth was not only unnecessary but also inherently unsustainable).

Natural Capitalism (Hawken, Lovins, and Lovins, 1999) starts from the basic premise that natural capital should be valued, as well as economic capital. Four central strategies of "natural capitalism" are proposed –

- Radical Resource productivity
- Biomimicry
- Service and flow economy
- Investing in natural capital

Triple bottom line

In terms of the definition of sustainability, the implication is that the three issues of social, environmental and economic sustainability should be considered.

Hopwood et al (2005) discuss the various definitions of sustainability as a prelude to mapping the different approaches and movements, concluding that they will use the phrase "sustainable development"

> *"...to describe attempts to combine concerns with the environment and socio-economic issues"*

- these two factors then being used as the axes on their map. Interestingly their environmental concerns axis goes from "Virtually none" to "Techno-centred" to "Eco-centred". Techno-centred equates to the weak natural capital preservation approach that says that it is acceptable to use up natural capital so long as it is replaced with man-made capital, while eco-centred equates to strong natural capital preservation, where replacement of natural capital with man-made capital is not acceptable.

Ecological footprint

> *"Ecological footprint studies evaluate how much bioproductive area is needed to produce the biomass consumed, to host the buildings and infrastructure, and to absorb the wastes (above all, CO_2) generated by a human population."*

(Haberl, Wackernagel, and Wrbka, 2004)

Thus, sustainability is the state when the sum of the footprints of all activities is less than the earth's total land area.

Sustainability and this research

It was found during the interview stage that companies reported fairly extensive enviromental impact reduction efforts but generally had addressed social sustainability far less, so the focus of this research was predominantly on environmental impact reduction and Lean. Therefore, the remainder of this overview will also focus on environmental impact.

2.3.2 Key environmental impacts

Life cycle analysis (LCA) methods (see section 2.3.3) require consideration and evaluation of all environmental impacts throughout the life cycle of a product, including its manufacture as well as its use, disposal etc. Hence, this list of environmental impacts from the report on the ReCiPe points-based LCA is taken to be comprehensive -

- climate change
- ozone depletion
- acidification
- eutrophication
- toxicity
- human health damage due to PM10 and Ozone
- ionising radiation
- land-use
- water depletion
- mineral resource depletion
- fossil fuel depletion

(Goedkoop et al, 1990, p.3)

2.3.3 Environmental impacts and their relevance to business and manufacturing

EEF and Envirowise identified a number of key environmental issues for UK businesses, which were energy usage, waste management, resource efficiency, carbon emissions, hazardous materials, noise, vehicle emissions, land contamination and odours. Companies were asked to identify three of these which were of most concern to them, and the list is presented in order of concern (highest concern first). The first two issues received by far the greatest number of positive responses, as 82% of companies picked energy usage and 70% water usage. The report attributes these concerns to costs, visibility and concern from businesses of all sizes (EEF & Envirowise, 2008).

The impact of manufacturing on the environment is considerable – for example, manufacturing is responsible for 27% of UK carbon emissions (Department for environment, food and rural affairs, 2009, p.34). Therefore concern for environmental protection indicates that reduction of impacts by manufacturing companies is desirable. The EEF / Envirowise survey showed that 91% of the businesses surveyed were acting to reduce at least some of their impacts and a further 7% were planning to take action.

Drivers identified by the survey conducted by EEF and Envirowise were (again, in decreasing order of importance to companies) legislation, adhering to EMS, customer requirements, board level support, reputation and brand integrity, regulators, increasing competitive advantage, shareholders or investors, voluntary industry initiatives, pressure groups (with “other drivers” coming in with around the same level of importance as voluntary industry initiatives and shareholders and investors) (EEF & Envirowise, 2008).

2.3.4 Mechanisms for reduction of environmental impact in manufacturing

A number of mechanisms have been proposed by which manufacturing companies can assess, monitor and record the environmental impacts of their products, processes and other activities and verify that plans to reduce impacts will be effective. Some of the more popular ones are discussed in this section.

Life cycle analysis (LCA)

> *“Life Cycle Assessment (LCA) models the complex interaction between a product and the environment from cradle to grave. It is also known as Life Cycle Analysis or Ecobalance.”*

(Pre Consultants, 2009)

Life cycle analysis can be an expensive and lengthy process but provides in-depth data on the environmental impacts. An LCA can be useful to manufacturing companies because it can show which activities, processes, materials etc. are creating particularly large environmental impacts, so that these can be targetted for improvement.

The process has two main steps: the inventory step, where the life-cycle of the product, service etc. is described and the raw material usage and emissions at each stage is recorded; and the impact assessment stage, where data is accessed to assess how much impact of what type is associated with the emissions and material usage.

Proxies

Proxy indicators are single indicators which can be used to estimate environmental impacts. Databases are available which provide the values for common materials, processes etc. Common proxies are -

- eco-indicators – a shortened form life cycle analysis method, where the various life-cycle impact scores are aggregated into single point scores. The methods used to aggregate the scores are controversial, especially as different databases can give very different results, but this method is much quicker than a full LCA.

- embodied energy – the indicator is the average amount of energy required to make a product.
- material input per unit of service – measures material input and transformation required to make a product, without accounting for the type of material used.
- ecological footprint values (see section 2.3.1)
- carbon emissions

(Lewis and Gertsakis, 2001)

Environmental Management Systems (EMS)

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

(Martin Baxter, 2004)

The standard for EMS is ISO 14001, which is based on Deming's cycle of plan, do, check, act. Companies are required to assess which are their main environmental impacts, then plan to reduce them. Elements of the EMS include workforce involvement and continuous improvement and also measuring, recording and auditing impacts and the efforts to reduce them.

Pollution control & pollution prevention

> *"Pollution control is an "end of pipe" approach and typically refers to the methods to trap, store, treat, and/or dispose of pollution after it is created. An example of pollution control is the installation of filters on smokestacks in order to prevent emissions from being discharged into the atmosphere. Pollution control is viewed as costly and nonproductive since it represents an expense that yields no potential for competitive advantage… …Pollution prevention reduces or prevents pollution and can result in lower costs Examples of pollution prevention include reducing the usage of resources, reducing the amount of waste generated, and recycling."*

(Rusinko, 2007, p.446)

Klassen (2000) notes a tendency among manufacturing companies to shift from pollution control (end-of-pipe solutions to reduce or remove pollutants, or remedial measures to treat the results of accidental emissions, breakages etc.) to pollution prevention (where the emission of pollutants or waste is reduced or prevented at source, preventing or reducing the requirement for remedial measures and often saving money).

Waste minimisation and efficiency

> *"What is resource efficiency?*
>
> *Resource efficiency is all about managing raw materials, energy and water in order to minimise waste and thereby reduce cost."*

(Business Link, 2010)

Commonly-reported strategies for environmental impact reduction include consideration of the amounts and types of raw materials, energy, or water used and the overall amounts of waste produced and how waste is disposed of (impacts are reduced by trying to reduce the amount of waste produced, by reusing material that would have been disposed of, by sending waste to be recycled where possible). Interview companies commonly reported that they were involved in recycling waste materials, reducing energy usage, substituting more benign materials and adopting waste reduction or zero-waste programs (see section 4.4.2) and the EEF and Envirowise survey showed that 62.3% of companies surveyed in 2007 had taken action to reduce energy usage; 52.4% had invested in energy-efficient equipment; 81% found recycling the most effective method of waste reduction and 16% favoured waste prevention. The same study reported that one company had reduced its production of mixed waste from two skip-fulls a week to 6 per year (EEF & Envirowise, 2008).

Environmental audits

Organisations such as Envirowise and the Carbon Trust and some companies provide environmental auditing services, offering to identify major impacts and provide guidance on reducing them. Services may have a particular focus (for example on energy efficiency or reducing waste to landfill).

2.4 Literature review of Lean and environmental improvement

2.4.1Literature search method

The first stage of the search was to find peer-reviewed papers that contained the word “Lean” and one or more of the words “green”, “sustainable”, “clean” or “environmental” in the title or abstract. This formed a body of work from which to begin writing lists of authors active in the field, journals that contained relevant articles, papers cited in these articles and papers that referred to these articles.

Further searches were run based on these lists. Each author’s list of work was reviewed and papers with titles referring to environmental improvement and/or manufacturing improvement were scanned for content relating to environmental impact reduction and Lean; searches were run within the contents of each journal identified using the same search terms noted above; references cited by or citing the articles previously found were scanned using the same criteria used to check key authors’ papers, noted above. The databases used for the initial searching procedure were ProQuest, EBSCO, Elsevier (Science Direct and SCOPUS), SWETS Wise Electronic Journals and Social Sciences Citation Index (ISI) – these sometimes found papers stored in other databases, which were then used for extraction.

As new papers were identified, new lists were generated, and the process was iterated until no more new papers were identified.

Where articles that were not peer-reviewed were referenced by several other papers or were by authors recognised in the main review with peer-reviewed papers, they were considered for inclusion in the main review. It was felt that this was appropriate given the limited amount of material available on the subject, and because articles relating to the results of integrated implementation of Lean and environmental improvement in a particular company were of interest to this review but were not peer-reviewed.

The research area which was to be reviewed thoroughly was Lean manufacturing and Lean thinking as relates to manufacturing, and its impact or potential to impact on environmental improvement. Several themes emerged within the group of papers that were referenced by or referred to the core papers, which were not within the locus of this research but sometimes overlapped it. These were Total quality management (TQM) and Total Quality Environmental Management (TQEM); Green supply chains; Just-in-time (JIT) as a separate improvement paradigm and Six-sigma. A full review of these subjects was not undertaken, but where papers were referred to by or themselves referred to the core papers many times, they were read and if they contained information that contributed to the emerging themes from the core papers, this was included.

Over the duration of the research, the iteration was repeated at intervals, with the last search being carried out just before submission.

The relevant papers located by this search procedure were read and the emerging themes were identified. The contribution made by each article was noted in terms of the themes they contributed to and the points they made within these themes, how these points compared to those made by other authors, and the validity and reliability of methods used to gather data to make those points.

The literature review is organised by the themes that emerged from the data.

2.4.2 Overview of papers found

Table 2.2 summarises the most important “environmental impact reduction and Lean” papers and is included here to give an overview of the available body of work. It can be seen from the table that there is not a great deal of work in this area; and that the earliest work dates from 1990, but that most was published after 2000.

Methods of research and themes identified are discussed later in section 2.4.2.

Details of the journals (or other sources) each piece of literature appears in are included in the table, to give assurance that most of these key papers have been peer reviewed.

Industrial sectors were not summarised in the table, but the range is fairly broad; as would be expected, the automotive industry was represented, but other papers studied include furniture manufacturing (Klassen, 2000), shipbuilding (Ross and Associates, 2004), aircraft manufacturing or US Airforce bases (Ross and Associates, 2003) (Ross and Associates, 2000), and a manufacturer of mirror-glass and glass for gauges

Figure 2.2 – Table summarising the key “environmental impact reduction and Lean”papers and reports

Ref	Findings	Methodology	Publication title & Validity
(Bergmiller and McCright, 2009a)	There are synergies between Lean and environmental improvement	Review of Shingo prize finalists and assessment of their environmental criteria by questionnaire	Industrial Engineering Research Conference
(Bergmiller and McCright, 2009b)	Lean companies have greater eco-credentials	Comparison of Shingo prize finalists eco-credentials and those of other manufacturers, by questionnaire	Industrial Engineering Research Conference
(Corbett and Klassen, 2006)	Expanding the horizons of analysis is what leads to the impact of “greening” on “Leaning” and vice versa (e.g. definitions, foci)	Literature review leads to research questions and conclusions	Manufacturing and Service Operations Management - peer reviewed
(Florida, 1996)	Lean creates incentives for environmental improvement, companies that innovate in Lean are more likely to do so in “environmental” ways, supplier relationship necessary for both, Lean and env. Impact reduction have common underlying principles.	Survey (random sample of 450 manufacturing firms drawn from a directory), phone interviews, field work (site visits and interviews)	California Management Review – peer reviewed

Ref	Findings	Methodology	Publication title & Validity
(Helper, Clifford, and Rozwadowski, 1997)	TPS as a focussing device.	Detailed interviews, statistical and qualitative analysis	Submitted to Academy of Management Annual Meeting 1997 available copy not peer-reviewed yet
(Jorgenson, 2008)	Sustainable management of companies requires integration of quality, environmental and H&S, in a lifecycle perspective and throughout the supply chain.	Discussion of standards, case study examining Danfoss' integrated management system.	Journal of Cleaner Production – peer reviewed
(Karp, 2005)	Using mapping and problem solving can help companies make impressive environmental impact and cost savings	Review of the work of the Green suppliers network with companies	Environmental quality management – peer reviewed
(King and Lenox, 2001)	Adoption of ISO 9000 means firms are more likely to adopt ISO 14000 and tend to show reduced waste and improved pollution prevention	Empirical analysis of 17499 US manufacturing establishments	Production and Operations Management - Peer-reviewed
(Klassen, 2000)	Pollution prevention can improve delivery performance	Field work and survey	Interfaces (Linthicum) – peer reviewed

Ref	Findings	Methodology	Publication title & Validity
(Larson and Greenwood, 2004)	The strengths and weaknesses of Lean and eco-sustainability mean there are important opportunities for integrating initiatives, potentially to the benefit of both.	Case study, after (Ross and Associates, 2000).	Environmental quality management – journal, peer reviewed
(Mason, Nieuwenheis, and Simons, 2008)	Environmental management can create “silos” – Lean can help avoid this, but companies need a simple way to work out their own impacts and VSM can be adapted to help them do this	Explaining a theory / method with worked examples.	Progress in industrial ecology
(Maxwell, Briscoe, Schenk, and Rothenberg, 1998)	Honda’s problem solving approach, employee involvement etc. contribute to good environmental performance	Case study, environmental impact reduction work at Honda of America, and analysis of reasons for success	Environmental quality management – journal, peer reviewed
(Maxwell, Rothenburg, Briscoe, and Marcus, 1997)	“Green schemes” can be profitable but require careful planning	Three case studies (interviews and other communications with officials)	California Management Review – peer reviewed
(Pil and Rothenberg, 2003)	Environmental improvement efforts can lead to quality improvements.	Surveys, quality metrics, in-depth qualitative data.	Production and operations management
(Ross and Associates, 2004)	Lean and EMS have similarities and synergies	Literature review and interviews	Work for US Environmental Protection Agency – not peer reviewed

Ref	Findings	Methodology	Publication title & Validity
(Ross and Associates, 2000)	Eco-sustainability can "ride the coat-tails" of Lean.	Case studies and theoretical extension.	Work for US Environmental Protection Agency – not peer reviewed
(Ross and Associates, 2003)	There may be a relationship between Lean and sustainability / resource efficiency	Lit review (also including net review etc.), telephone interviews with industry and NPO Lean experts, case studies (review of public data and phone interviews, only one site visit)	US Environmental Protection Agency sponsored research, not peer reviewed.
(Ross and Associates, 2008)	Integration gave better cost savings, waste reductions and environmental improvements.	Case studies at three companies aided by environmental and Lean advisors; Evaluation of deliberate integration of Lean and environmental improvement.	US Environmental Protection Agency sponsored research, not peer reviewed.
(Rothenberg, 1990)	Implementing Lean affects environmental performance	Literature review, survey, case studies (not Action Research)	PhD thesis
(Rothenberg, 2003)	Workforce and specialist participation is necessary in environmental improvement efforts	Case studies – including interviews with participants in "quality circles".	Management studies – peer reviewed

Ref	Findings	Methodology	Publication title & Validity
(Rothenburg, Pil, and Maxwell, 2001)	Different aspects of Lean (buffer minimisation, work systems, workforce relationships) contribute to improved resource efficiency; Lean plants more likely to have high VOC emissions	Survey and interviews	Production and Operations Management – peer reviewed
(Simons and Mason, 2003)	Environmental management can create "silos" – Lean can help avoid this, but companies need a simple way to work out their own impacts and VSM can be adapted to help them do this	Explaining a theory / method with worked examples.	Efficient Consumer Response journal – not peer reviewed
(Soltero and Waldrip, 2002)	Kaizen can be used to improve both productivity and environmental performance	Describe and define kaizen and how to do it. Application to environmental improvement mentioned occasionally	Environmental Quality Management – journal, peer reviewed
(Soltero, 2007)	Goal setting can improve performance (including environmental)	Explanation of existing techniques and assertion that they work for any goal – no examples/cases	Environmental Quality Management – journal, peer reviewed
(Thornton, 2000)	Integration of ISO 14001 can help to ensure environmental improvement potential of Lean is realised.	Opinion piece	Environmental Quality Management – journal, peer reviewed

Ref	Findings	Methodology	Publication title & Validity
(Tice, Ahouse, and Larson, 2005)	Lean and EMSs are "fundamentally different" (drivers and approaches) but can be "both compatible and synergistic", (linked to Ross and Associates)	Literature, interviews, case studies	Environmental Quality Management – journal, peer reviewed
(Vais, Miron, Pedersen, and Folke, 2006)	"Lean and green" production can help to ensure compliance with IPPC and wastewater regulations	Implementation / project in Romanian paper mill	Resources, Conservation and Recycling – peer reviewed

(Wlodarczyk, Pojasek, Moore, and Waldrip, 2000) and many did not limit their search by industry. The majority of the research comes out of the USA and Canada.

Methods of research

The methods of research used are included in table 2.1 because they affect the nature of the findings of research in this area.

Many researchers used questionnaires and surveys to find out about companies' existing Lean implementations and their effects on environmental impacts and strategies. Some researchers then analysed these using a variety of statistical methods to try to establish links between certain Lean practices and certain indicators of environmental improvement, for example, some made qualitative analyses of the results, and many used a combination of these methods (e.g. Helper et al, 1997)

Some researchers carried out more in-depth interviews, often as a second stage of research after having carried out questionnaires and surveys (e.g. Florida, 1996; Rothenburg et al., 2001)

Some surveys and questionnaires used companies selected as finalists for competitions as their target group – for example, Bergmiller and McCright's two papers (2009a; 2009b) use submissions for the Shingo prize to establish their target group's Lean credentials.

There are some papers and articles that relate case studies and professional experience in companies that are using some Lean methods or tools for environmental improvement (e.g. Farish, 2009; Jorgenson, 2008; Maxwell et al, 1998; Maxwell et al., 1997; Ross and Associates, 2000; Ross and Associates, 2003; Rothenberg, 2003) Karp and Mason, Nieuwenheis and Simons discuss the modification of particular tools and their application in companies (Karp, 2005; Mason et al, 2008).

Finally, some papers are discussions of the author's suggested methods for using Lean tools and ideas for environmental improvement, which do not discuss any cases where these ideas have been applied (e.g. Pojasek, 1999; Soltero, 2007; Thornton, 2000)

Dominant themes in the "environmental impact reduction and Lean" literature

The general consensus is that Lean can reduce environmental impacts (with the caveats in sections 2.4.8 below) but authors have differing ideas on exactly how; these are categorised as: "side effects" (where researchers have looked for the effect of Lean, as it is normally implemented, on environmental impacts, when there is no particular intention to reduce environmental impacts); Lean as a way to achieve goals (discussions on how the reduction of environmental impact could be one of the goals set for the Lean implementation, alongside the operational improvements); Aims of Lean (how do the main aims of Lean tie in with environmental improvement aims and goals?); Particular Lean tools and their current and potential environmental effects (where researchers have commented on the potential for particular Lean tools to be used or adapted for the purpose of reducing environmental impacts); and finally, culture and learning style (how does the culture fostered by Lean affect the ability to make environmental improvements?)

2.4.3 Environmental "side-effects" of Lean

> *"At each of the shipyards, interviewees had examples of how Lean activities have resulted in improved environmental outcomes, as the following anecdotes illustrate. Most of the evidence available is anecdotal because the companies have not yet collected much data on the environmental improvements resulting from their Lean activities."*
>
> (Ross and Associates, 2004, p.7)

This section discusses the findings of authors who have looked for the environmental "side-effects" of Lean as it is for environmental improvement; where there was no particular intention to make environmental improvements, they have occurred as "happy accidents".

Ross and Associates (2000; 2003; 2004) find that companies have made environmental impact reductions incidentally from their Lean implementations. One of their papers (Ross and Associates, 2004) states as a finding that the environmental benefits of Lean are currently "opportunistic" meaning that they are unintentional or not formally integrated – but they note that companies are beginning to head towards integration.

They also state that companies only rarely measure the environmental effects of their Lean implementations; and when they do measure these effects it is only the most direct that are recorded. They suggest the following possible environmental benefits which are not so direct, and therefore not recorded –

> • Reduced demand for raw materials avoids environmental impacts from their extraction, processing, and transport;
> • Higher quality products often have greater longevity, decreasing the frequency of product repair and replacement and the associated environmental impacts; and
> • Lean design for manufacturability can reduce the number of parts and materials in a product, and therefore may make it easier to recycle products or product components.

(After Ross and Associates, 2003, p.27)

Sawhney, Teparakul *et al* (2007) noted in a literature review that there is some disagreement about the environmental effects of Lean, and suggest that the reasons for this are that researchers often consider individual elements of Lean rather than its overall effect, and often do not restrict their considerations to specific processes.

Klassen (2000) carried out interviews and a survey, presenting qualitative and quantitative data to assess the links between adoption of pollution prevention practices, JIT, delivery performance and environmental performance. He measured the amount of money spent on pollution prevention to judge the extent of its adoption, and the weight of "toxic releases and transfers", without rating their severity, to judge environmental impact. Statistical analysis of these data form one part of the paper and discussion of results of interviews with managers which attempted to ascertain their thoughts on the environmental effects and possibilities of manufacturing strategy formed another. His statistics show that although investments in reducing setup times and in relationships with suppliers were not statistically linked to his chosen indicators of improved environmental performance, an increase in overall investment in JIT is weakly linked to reduction in environmental impact. His interviews showed that managers were not generally aware of the environmental benefits brought about by, for example, practices that reduce the amount of material consumed.

Rothenburg (1990) also used statistical methods to show weak links between some aspects of Lean and some aspects of environmental improvement (e.g. process improvement is weakly linked with reduction in VOC emissions). A later, collaborative paper (Rothenburg et al., 2001) also shows weak statistical links but the qualitative results from interviews are stronger.

However, other authors found stronger links. Florida, Atlas *et al* (2001), find strong links between some organisational factors that are similar to the symptoms of Lean and adoption of environmental innovations, in a statistical survey. King and Lenox (2001) use empirical analysis on a survey of 17,499 US manufacturing companies and find that Lean companies reduce emissions and are more likely to adopt ISO 14001 and to use source-reduction rather than end-of-pipe methods. Their Lean indicators are adoption of ISO 9000 and reduced chemical inventories.

A survey of Shingo prize winners and finalists showed that those with stronger environmental performance also reported better Lean performance. The improvement in Lean performance shown by cost indicators in these companies was particularly marked (Bergmiller and McCright, 2009a), and the survey also showed that companies implementing Lean reported higher "environmental" indicators than a survey of the wider manufacturing community (Bergmiller and McCright, 2009b).

Another point made in the Ross and Associates group of papers is that integrating environmental impact reduction into Lean could have benefits for Lean manufacturing too, by filling some of its "blind spots". For example:

> *"FINDING 4: EMS Improves / Adds Value to Lean*
>
> *Interviewees believed that an EMS can add value and improve the implementation of Lean methods and activities. An EMS can expand the focus of Lean activities by redefining of "waste" to look beyond typical production waste. EMS can also help Lean*

> *address environmental "blind spots," such as the risk or toxicity of materials used and the full life-cycle impacts of products and processes. For example, an EMS can help focus attention on materials substitution, such as using low volatile organic compound (VOC) paints, which might not be considered under Lean (e.g., if high-VOC paints cost less or the same)."*

(Ross and Associates, 2004, p.7)

The expansion of scope via the redefinition of waste seems to have potential as an improvement on Lean, especially as things like energy and waste disposal costs are now having more impact on companies' costs, but the other improvements to Lean seem to have more effect upon its environmental impacts than its productivity impacts. Pil and Rothenburg (2003) found correlation between environmental improvement factors and quality improvements, which led them to surmise that environmental improvement can drive quality improvement; similarly, Rajaram and Corbett (2002) found that increased environmental constraints caused efforts to prevent pollution with associated significant improvement to processes.

Klassen (2000) found that although overall the proportion of a plant's capital budget dedicated to environmental improvements did not affect delivery performance, if the proportion of the environmental expenditure spent on pollution prevention (as opposed to end-of-pipe measures or management systems) was greater then improved delivery performance was also likely.

Larson and Greenwood also comment on the key difficulty with these incidental environmental improvements – that Lean as it stands will focus on the "expensive" environmental wastes only –

> *"To the extent that environmental risk translates into high relative costs for a company, Lean is likely to zero in on the risky material, process, or product with redesign changes—but only because it is a high-cost item, not because it has high environmental risk. In instances where environmental costs are relatively low, Lean is likely to skip right over a risky material, process, or product and focus its resource productivity efforts on areas of higher cost."*

(Larson and Greenwood, 2004, p.31)

Thornton (2000) agrees that Lean may or may not have environmental improvement side-effects and suggests the implementation of ISO 14001 in conjunction with Lean to ensure companies consider environmental impacts and gain benefits from their reduction.

Discussion - These findings form a solid base to build new research on, by showing that **Lean as it is normally implemented is capable of providing environmental benefits even though there is no direct intention to reduce environmental impact** [I2-1]. They also show that these benefits may not always be gained because those implementing Lean are not looking for them and they are not goals of Lean – suggesting that acknowledging environmental improvement as another aim of Lean might help to ensure companies gain from this added value. In other words, **these incidental gains themselves are just as valid as "intentional" gains, but if the company is not aware of them they will not learn to look for others that do not occur as natural side effects** [I2-2]. However, there is a fine division between a healthy encouragement to seek out the "non-automatic" Lean-environmental opportunities, and allowing a perception that the Lean-environmental tools are pushing too far towards environmental impact reduction changes that are less beneficial to productivity than other Lean changes (see (Ross and Associates, 2003) for the argument against "painting Lean green", which they state would be resisted by companies and proponents of Lean).

The choice of predominantly expenditure-based indicators for the statistical analysis seems strange in Klassen's paper because one of the features of Lean is the ability to make changes without requiring much capital expenditure, but the more enlightening material in his paper is drawn from interviews anyway. The statements that **the addition of environmental considerations to Lean can add value to the Lean implementation** [I2-3] is interesting as it may affect the uptake of the combined tools.

2.4.4 Lean is a way to achieve many kinds of goals

> *"Lean in general (and hoshin kanri in particular) can be positively applied to any aspect of an organization's continued sustainability"*
>
> (Soltero, 2007, p.36)

Soltero (2007) suggests that Lean provides a method for achieving whatever goals a company sets – whether they are related to reducing costs, improving quality, reducing environmental impact, improving safety, or any other issue that the company wishes to act upon. He takes the view that Lean is not a set of tools that should be applied in a particular order but that it provides tools which should be chosen according to the goals that the company is trying to achieve or the problems it is trying to solve. Unfortunately the paper does not report the results of trials with companies, or indeed whether any have been conducted.

Ross and Associates' (2004) recommendation is to -

> *"Use Lean methods to meet EMS and other performance objectives"*

(Ross and Associates, 2004, p.10)

They suggest focusing Lean efforts in areas with particular environmental issues in order to address these, which is a slightly different suggestion to Soltero's addition of environmental goals to the overall implementation – although the effects would probably be quite similar.

Discussion – These two papers propose that **the Lean methodology can be used to make environmental improvements as well as productivity improvements** [I2-4].

2.4.5 Key aims of Lean and the link to environmental improvement

Inventory reduction / buffers

> *"The introduction of a "Kanban" cart system to the 747 wing panel inventory and supply system has eliminated utilization of 350 cubic feet of cardboard and bubble wrap packing material per wing ship set"*

(Ross and Associates, 2000, p.13)

Reduction of "buffers" and inventory in general has been mentioned by several authors but is not such a popular synergy to discuss. Ross and Associates (2000) briefly mention the reduction in floorspace, and thus heating, lighting, etc., caused by reducing inventory – but these savings would only really come into play where a business is looking to acquire new premises (and thus could save space and stay in the existing ones) or can save enough space to move all their operations into a smaller building. They also report reduction in wastage of out-of-date supplies due to reduction in inventory held (see section 2.4.6 – Just In Time for more details), and, as in the quote above, reductions in packaging that are a side-effect of introducing a kanban system (presumably for shipping goods in from another site or from a supplier, rather than internal kanban) to reduce inventory.

Rothenburg *et al* (2001) on the other hand make buffer reduction a key point in one of the hypotheses for their paper, stating that buffer reduction **-**

> *"reduce*(s) *the likelihood of large batches of faulty material and reducing in-process waste"*

(Rothenburg et al., 2001, p.229)

- but their statistical results did not show a strong overall link between buffer reduction and environmental impact reduction, and they found that reductions in incoming inventory were statistically linked to an increase in energy and water use. A possible explanation for this was suggested – older non-Lean factories may have made efforts to reduce incoming inventory without adopting other aspects of Lean. However, in the interview results the buffer minimisation is used simply as an indicator of Lean practices and linked to pollution prevention rather than end-of-pipe measures.

<u>Discussion</u> – These papers show that **reduction of inventory (for example by implementing kanban) can lead to various benefits that are both "Lean" and "environmental"** [I2-5]. The packaging reduction due to kanban that is noted in Ross and Associates paper is interesting, and does not appear in any other papers.

Overall, this section provides a good example of the way environmental impact reduction and Lean can work together.

Kaizen (including Kaizen events, Kaizen blitz or Kaikaku), Continuous Improvement and workforce involvement

> *"Using Kaizen as a foundation for pollution prevention and Lean manufacturing can create sustainable results through total enterprise involvement"*

(Soltero and Waldrip, 2002, p.23)

Soltero and Waldrip (2002) devote their whole paper to the Kaizen improvement method, explaining its use in general, and in particular for environmental improvement, stating that it provides a method for companies to systematically reduce "pollution volume and severity" by making continual small improvements (as opposed to the "radical innovation" approach). They also state that it is possible to achieve greater gains from this type of Continual Improvement (CI) than from investments in new technologies and suggest that CI encourages consideration of the whole system, while radical improvement can tend to focus only on one part of the whole system. They explain that as well as being based on continual small Improvements, Kaizen is done predominantly by the workforce, thus using all the available creativity and experience. They advocate a three step Kaizen program – Standardise processes, Simplify (by which they mean removing wastes in the process, for example by applying a Lean approach), and finally Eliminate remaining variation (for example by using six sigma tools). Pojasek's (2008) paper focuses on the need to integrate all programmes within a company that require or drive CI, and Jorgensen (2008) comments on the development of an integrated management system at Danfoss, where CI is a link between the Lean implementation and environmental improvement. The Romanian paper mill project paper (Vais et al., 2006) reports that Kaizen was used to change attitudes to housekeeping and water/wastewater management.

Sarkis (1995) mentions CI as a TQM tool for waste reduction which could also be used to reduce environmental wastes. Tice and Ahouse (2005) suggest that the common reliance on CI is a synergy between Lean and Environmental Management Systems and Larson and Greenwood (2004) make some mention of the value of CI and workforce engagement for environmental improvement. Wlodarczyk et al (2000) suggest that the capacity for CI be built into solutions to problems. They point out that as well as "many heads being better than one", involving more people in the problem-solving process improves buy-in to the solutions.

The value of involving the workforce in environmental improvement was a common theme (e.g. Hanna, Newman, and Johnson, 2000) and authors report that companies have found that their workforce can make suggestions for environmental improvement. Workforce involvement was linked to environmental impact reduction as early as 1996 (although not in a Lean context) in a study of data from 1991-1992 (Bunge, Cohen-Rosenthal, and Ruiz-Quintanilla, 1996), relating to a recent requirement by the US EPA that companies report human resource management strategies they developed to reduce the likelihood of toxic releases at source. The study finds that there is a link between serious, organised effort to collect "employee recommendations" for improvement and a reduction in pollution. Farish (2009) reports that Toyota have used Kaizen to reduce environmental impacts such as waste to landfill, energy and water usage, by implementing suggestions from the workforce. Soltero and Waldrip (2002) stress the importance of training the workforce in Kaizen techniques for environmental impact reduction at several points in their paper.

Rothenberg, Pil and Maxwell (2001) found that CI suggestions about reduction, reuse and recycling of materials and consumables were being made. Analysis of suggestions in one plant found that 8.5% had the potential to reduce environmental impacts. Florida's (1996) surveys showed that 64.6% of companies involved line workers in their pollution prevention programmes and follow-up phone interviews revealed that interviewees found that worker involvement and CI produced environmental and financial benefits. A later collaborative paper (Florida et al., 2001) finds that involvement of shop-floor operators, and CI-style improvements, are important to their environmental improvement efforts (one plant reported that all their environmental improvement ideas originate from the shop-floor, and another attributes around two-thirds of their environmental improvements to shop-floor suggestions). Companies seemed to be linking these improvements to their Lean implementations. Ross and Associates (2008) reported that companies had successfully used CI to generate environmental improvements.

Rothenberg's (2003) case study at NUMMI, a joint GM-Toyota plant, also found that workforce involvement helped the plant to make environmental improvements and Lean improvements. She found that nearly half (47%) of the environmental improvement projects she analysed involved participation from shopfloor workers, although roles were often quite passive – the largest proportion were "receiving training on how their job would change", followed by consultative roles. She points out that it is important to note the conditions in which this workforce suggestion scheme was set up, for example the atmosphere of trust between workforce and management and the availability of specialist staff to discuss potential suggestions with the workforce and carry out the suggested projects; although worker participation is important it is also vital to have specialist input, as environmental improvement projects are often initiated by management and engineers. In this respect, environmental improvements were different to process improvements which were more often initiated "bottom up".

Kaizen events are another of the tools that Ross and Associates (2004) recommend for use in environmental improvement. They report companies using an environmental checklist during all Kaizen events, involving EHS staff in Kaizen events, and running Kaizen events with the aim of (although not limited to) reducing environmental impacts (see also Ross and Associates, 2008), all producing improvements that reduced emissions and costs.

Discussion – **Kaizen/Continuous Improvement (CI), kaizen blitz and workforce involvement and suggestions are popularly suggested methods of gaining environmental benefit from a Lean implementation** [I2-6]. Perhaps this is partly because CI is already a part of many EMS programmes (although CI in environmental programmes may not be defined in exactly the same way that Lean defines it) and a requirement of ISO 14001, so papers that mostly deal with the overlap of Lean "as is" rather than proposing modifications are likely to pick up on this synergy which can already be seen in companies.

Standard work & Visual control

> *"EMS Responsibilities and procedures can be incorporated into the Standard Work and Visual Controls used in Lean"*
>
> (Tice et al., 2005, p.11)

Ross and Associates (2004) suggest as one of the conclusions of their report that standard work can be used to ensure that everyone complies with environmental best practice.

Tice, Ahouse *et al* (2005) also mention that the disadvantage of Lean for environmental improvement is the tendency for Lean companies' standard work procedures to change relatively frequently, for example due to Continuous Improvement schemes, means that they must be careful to review new procedures for EMS compliance, and integrate best environmental practice for new procedures.

Discussion – It is possible that **the ability to integrate environmental best practice into standard work could be a benefit of integrating environmental improvement with Lean** [I2-7], but this was not an idea widely mentioned.

Waste and Value

> *"both Lean and EMS focus on eliminating waste, although there are differences in the scope of how "waste" is defined"*
>
> (Ross and Associates, 2004, p.4)

Possibly the most obvious link between Lean and environmental impacts is that both are interested in waste, and some authors mention this (e.g. Bergmiller and McCright, 2009a; Edwards and Jonkman, 2001; Larson and Greenwood, 2004; Rothenburg et al., 2001; Sarkis, 1995; Weinrach, 2002) Ross and Associates (2003) report that all the managers they interviewed agreed that both Lean and EMSs focus on waste reduction, and provide a table to show how environmental impact fits with Lean's seven wastes (see Fig. 2.2).

Braungart, McDonaugh and Bollinger (2007) discuss waste in terms of their cradle-to-cradle philosophy of eco-efficiency; in contradiction to most authors of "environmental impact reduction and Lean" papers, they state that waste should not be reduced, it should be segregated so that biodegradable waste will be composted and feed the land, technological waste will be recycled and feed industrial processes. Further, they blame Lean for contributing to globalisation and thus for difficulties in identifying materials for waste segregation at end of life. However, Gutowski *et al* (2005) noted that Toyota actually do segregate even their floor sweepings for recycling, have very low waste to landfill per car, and have invested effort in design for waste segregation, because -

> *"when combined it is waste, but when sorted it is resource"*

(Gutowski et al, 2005, p.4)

Farish (2009) corroborates the scale of waste to landfill reductions at Toyota and also reports reductions in other environmental measures such as water and energy usage, which are attributed to kaizen and workforce involvement.

Several researchers, while agreeing that there is a link between waste reduction for Lean reasons and for environmental improvement reasons, point out that the definitions are different:

> *"Environmental wastes (such as pollution and environmental risk) are not explicitly included in the wastes targeted by Lean. However, Lean production naturally reduces some of these environmental impacts because of its inherent waste elimination focus."*

(Tice et al., 2005, p.3)

> *"With regard to wastes, an EMS takes a narrower focus than Lean by targeting only those wastes that have environmental implications."*

(Ross and Associates, 2004, p.4)

It is fundamental to Lean to understand that the opposite of waste is value, and many authors also mention the importance of value to customers when writing about environmental improvement efforts. Beechner and Koch (1997) point out that understanding what customers' requirements are is necessary for both ISO 9001 and ISO 14001. Waldrip (1999) comments that

Figure 2.3 – Table summarizing environmental impact and waste

Waste Type	Examples	Environmental Impacts
Defects	Scrap, rework, replacement production, inspection	• Raw materials consumed in making defective products • Defective components require recycling or disposal • More space required for rework and repair, increasing energy use for heating, cooling, and lighting
Waiting	Stock-outs, lot processing delays, equipment downtime, capacity bottlenecks	• Potential material spoilage or componentdamage causing waste • Wasted energy from heating, cooling, and lighting during production downtime
Over-production	Manufacturing items for which there are no orders	• More raw materials consumed in making the unneeded products • Extra products may spoil or become obsolete requiring disposal
Movement	Human motions that are unnecessary or straining, carrying WIP long distances, transport	• More energy use for transport • Emissions from transport • More space required for WIP movement, increasing lighting, heating, and cooling demand and energy consumption • More packaging required to protect components during movement

Inventory	Excess raw material, work-in-process (WIP), or finished goods	• More packaging to store work-in-process • Waste from deterioration or damage to stored WIP • More materials needed to replace damaged WIP • More energy used to heat, cool, and light inventory space
Complexity	More parts, process steps, or time than necessary to meet customer needs	• More parts and raw materials consumed per unit of production • Unnecessary processing increases wastes, energy use, and emissions
Unused creativity	Lost time, ideas, skills, improvements, and suggestions from employees	• Fewer suggestions of P2 and waste minimization opportunities *(Note - P2 = Pollution Prevention in normal US usage)*

(after Ross and Associates, 2003, p.32)

environmental improvement is only of benefit to customers if it adds value for the customer to products, and states that if changes to processes for any reason are to be beneficial to the company, then -

> *"Productivity, profitability, customer satisfaction, and worker satisfaction are all equal measures of sustainability and must be considered along with those proposed by the environmental community"*

(Waldrip, 1999, p.43)

Martin (2005) discusses the ways that various aspects of waste reduction for environmental improvement can add value to the company: enhanced compliance (avoiding fines and keeping licenses to operate), pollution prevention (reduction in raw materials and cost of waste disposal, reduction in cost of handling hazardous materials, and potential softer gains for example from improved working conditions), risk reduction and proactive management (avoiding or minimising the costs of reacting to accidental spillages etc.), and enhanced marketability (some consumers might be willing to pay more for "environmentally friendly" products and these practices might improve the company's reputation). Helper *et al* (1997) point out how data gathered on waste for environmental management reasons may be used to improve quality, and citing the example of tool wear (at an aluminium casting facility, the environmental manager had proposed that worn dies, produced more flash and more waste fluids. The amounts of both were already measured for environmental compliance reasons, but these measurements could be monitored and used to trigger die replacement before quality issues resulted).

The Martin paper does not mention Lean by name, and there are several other authors who mention waste and/or value in an environmental context but do not mention Lean. For example, Maxwell *et al* (1997) also mention the importance of improving value and the part environmental impact reduction plays in improving the all-round value of a business - but it is written by authors who have also contributed to the "environmental impact reduction and Lean" field. Likewise King and Lennox have a paper on "Lean and green" (King and Lenox, 2001) which is discussed at various points in this review; in a later paper they do not mention Lean but do argue that it is the prevention of waste that leads to the profits reported from environmental improvement (King and Lenox, 2002). Theyel's (2000a) paper also does not use the word Lean, but finds that "waste audits" are the most popular of the pollution prevention methods he offers in a questionnaire presented to US plastics and resins manufacturers, although he notes that definitions of a waste audit vary greatly – and he also finds that there is a strong statistical link between waste auditing and process change for environmental improvement. Sarkis (1995) discusses waste in the contexts of TQM and JIT.

Authors report that zero-waste strategies are popular as an environmental improvement method with some companies – for example, Florida (1996) points out that, in the same way that "zero defects" is considered to be a target to aim for rather than something that is necessarily achievable with current technologies, zero-emissions manufacturing is also seen as a target by some 16% of companies (compared to 85% pursuing reduced emissions manufacturing). Although Florida's telephone interviews and site visits suggested that most don’t see it as realisable, they say that these ambitious goals (whether zero-defects or zero-emissions) help to drive improvement to new levels.

Discussion – The majority of authors agreed that **the identification and reduction or elimination of waste is important to both Lean and environmental improvement but definitions of waste are different** [I2-8]. Authors also discussed the value of reduction of environmental impacts and wastes, for the customer and for the company. Florida’s point about the aspirational nature of completely eradicating defects or emissions is interesting also. Farish (2009) and Gutowski *et al* (2005), among others, suggest that companies have made use of this synergy.

2.4.6 Particular Lean tools and their current and potential environmental effects

Value Stream Mapping

> *“Research is now showing that one of the tools developed to operationalise Lean thinking – value stream mapping – can be adapted to operationalise green thinking too”*
>
> (Simons and Mason, 2003, p.85)

Value stream mapping (VSM) is the mapping of wastes throughout the organisation, and is a fairly commonly noted tool for both Lean and environmental improvement. For example, Ross and Associates (2004) suggest that companies integrate value stream mapping and EMS Impacts and Aspects analysis, noting the similarity of the two activities (recording the steps in a process, analysing which steps have the most impact, and making plans to address the findings) and stating that combining the two would allow companies to make more holistic future plans which meet all the companies objectives. A later report (Ross and Associates, 2008) documents the successful use of mapping in case study companies to identify larger sources of environmental waste. A report on process efficiency improvements in Australian timber furniture supply chains (Schliephake, Stevens, and Clay, 2009) used mapping of material flows to highlight inefficiencies, with the potential for significant savings in financial and environmental terms. Wlodarczyk *et al* (2000) present a systems approach to making environmental improvements, which does not specifically mention Lean, process improvements or Value Stream Mapping, but starts with a process map. The map shows the steps in the process and how they relate to one another, and how material flows through the processes, and is hierarchical – the top level map is to have no more than six steps, with each step then having its own map showing the steps within that step in more detail, and so on as required for successive levels each showing finer detail. In their proposed problem-solving methodology the map is used to identify problems -

> *"where losses are occurring and where pollution is being created"*
>
> (Wlodarczyk et al., 2000, p.55)

- which are then prioritised for action, investigated for root causes, have potential solutions generated, discussed and chosen, and finally action plans for change created. They suggest the use of costs of environmental impacts to rank the environmental problems for action

> *"since improving environmental performance really means preventing costly losses"*
>
> (Wlodarczyk et al., 2000, p.55)

Some researchers note the similarity of Value Stream Mapping to Life Cycle Analysis (LCA) – for example, Larson and Greenwood (2004) who point out that -

> *"the systemic evaluation of waste throughout the product value chain"*
>
> (Larson and Greenwood, 2004, p.33)

- in Lean and EMSs mirror each other closely, and that carrying out a Life-cycle analysis will be much more cost-effective for a Lean company (implying that it would be based on the VSM that they already have).

Simons, Mason and Nieuwenheis' papers (Mason et al, 2008; Simons and Mason, 2003) are dedicated to the subject of "Sustainable Value Stream Mapping". They suggest that carbon dioxide should be added, as a proxy for environmental impact, to the value stream map. They state that this will avoid the deleterious effect of environmental "siloism" or the consideration of environmental impacts strictly divided into processes and business activities, without considering the whole – benefiting in a similar way, in fact, to Lean's consideration of value streams and product families rather than functionally-defined departments.

Theyel's (2000b) paper on popular environmental improvements and their comparison to TQM finds that "waste audits" are the most popular pollution prevention method in the companies he surveyed. Further investigation showed that the definition of a “waste audit” varied significantly but one of the definitions given tallied closely with an environmental-impact oriented VSM.

The Green Suppliers’ Network uses current and future state mapping to help companies identify potential environmental improvements (Karp, 2005).

Discussion – The range of literature on mapping draws parallels between value stream mapping and a number of different environmental improvement activities. This is not really surprising because it makes sense to know exactly what the current situation is, before trying to make any change. Mapping forces the current situation to be documented, which helps to expose any uncertainties.

The possibilities proposed, in the “environmental impact reduction and Lean” literature, for using mapping for environmental improvement fall into three groups; the use of mapping to ensure a thorough understanding of the current and proposed processes; the use of mapping to identify where the main areas of (environmental) waste are; and its use to promote a holistic view (by product families rather than departments) thus avoiding “silos” [I2-9].

With respect to the use of mapping to locate the main environmental wastes in a value stream, it would be necessary to define environmental waste more accurately for environmental VSM to work in this way unless impact was assessed purely using a proxy or points system (see below) which in effect is a pre-ordained definition of waste.

The idea of using a proxy for environmental impact and adding that to the VSM is interesting. Although it would not give nearly as much information as a full LCA and the use of a proxy (or a points system such as PRe’s Ecoindicator would be an alternative, with the advantage that the impacts are already calculated for most standard materials and activities) can sometimes lead to inaccuracy (PRe consultants, 200; Ross and Associates, 2000), this could be a faster and lower-cost way (since a VSM exercise takes hours to complete, whereas an LCA can take months or even years) for companies to get an idea of where their biggest impacts lie so that they can focus their environmental improvement attention here first.

The final point to re-emphasize here is the avoidance of siloism. This is interesting both on a practical level and because it is one of the less immediately obvious parallels between the requirements for Leaning and environmental improvement, i.e. the need to ensure that an action taken to improve in one area does not have unexpected and unhelpful consequences in another.

Goal setting & Performance management

> *"For hoshin kanri to work, all strategic initiatives across the entire organization must use the approach uniformly as the deployment mechanism. Through the supple integration of environmental goals and Lean strategic initiatives, an organization can actualize its environmental vision while achieving the financial benefits typical of Lean implementation"*
>
> (Soltero, 2007, p.36)

Soltero's (2007) paper provides a thorough description of goal setting or Hoshin Kanri (also referred to as the golden needle, shining compass, or, less poetically, policy deployment). Briefly, Hoshin Kanri involves setting objectives for the business then cascading them down through the organisation so that it is clear how each individual's roles and responsibilities contribute to the overall objectives. Soltero argues that Hoshin Kanri should be applied to all an organisation's objectives and strategies, including environmental objectives and others as well as those traditionally associated with Lean. Sarkis (1995) is not as definite as Soltero on goal setting, but nevertheless it forms the first of his five steps for Environmental Change Management project plans, and guides all the other steps. Beechner and Koch (1997) explain that it is required for both ISO 14001 and ISO 9001 that clear objectives are set and responsibilities for meeting different aspects of these objectives are defined. Florida *et al* (2001) found that there was a strong statistical correlation between performance measuring and Environmentally Conscious Manufacturing adoption, with performance measurement in their survey consisting of setting environmental goals and monitoring environmental performance. They also found that all companies in the sample that had adopted Environmentally Conscious Manufacturing processes communicated their environmental goals and progress to the workforce, while only one of the non-adopters did so.

Ross and Associates (2004) state that their research shows that environmental improvement is rarely an objective for Lean (although Lean does provide some environmental improvement anyway); Tice *et al* (2005) agree and suggest that benefits could be gained by integrating environmental objectives into the Lean implementation.

Discussion – “environmental impact reduction and Lean” authors were agreed that **goals for environmental improvement should be set, for all levels within the organisation, and communicated well** [I2-10]. None of the authors mention the particular advantage of goal setting for environmental improvement – for example, that it might allow non-environmental-expert Lean teams to learn about and act to reduce a selected number of environmental impacts at a time rather than trying to take on the whole bewildering gamut. Hoshin kanri may help here as Soltero suggests, by ensuring that everyone in the organisation has environmental goals that they can act on, and that they can see how these goals are necessary to meet the organisation’s strategic goals.

5S

> *“RAFB Lean teams used an adapted version of 5S… (and they) …reduced emitted VOCs; … reduced the number of chemicals used from nine to three, as well as the overall amount of chemicals used; reduced storage space by 228 square feet; and generated $373,800 in direct operating saving”*
>
> (Ross and Associates, 2003, p.68)

5S is a popular tool used by companies to clean and rationalise areas within their works, removing unwanted parts, tools and general detritus and setting a new standard for cleanliness and tidiness. It is also a way to help participants look at their workplace in a new way. However it is not mentioned much in the “environmental impact reduction and Lean” literature.

Ross and Associates (2004) do mention it: in the context of introducing waste segregation bins during a 5S exercise, and using 5S to reduce internal transport of hazardous materials, thus reducing transport impact as well as leaks and spills – and, in another report (Ross and Associates, 2003) mention the reductions in storage space, chemical usage and VOC emission after a 5S-based exercise. The Romanian Paper Mill “environmental impact reduction and Lean” project (Vais et al., 2006) used 5S and states the benefits for health and safety and housekeeping, but not how this affected the environmental outcomes of the project – although they imply that it did have an impact.

Discussion **- 5S schemes can result in environmental improvement side-effects and can be adapted for intentional environmental improvement** [I2-11] through the introduction of segregated waste bins, reduction of storage space and reduction of wasteful activities liable to cause environmental wastes**.**

Just In Time

> *"Investments in both JIT and pollution prevention may yield overlapping benefits"*
>
> (Klassen, 2000, p.98)

Just-in-time means different things to different people. Within the context of Lean it tends to mean the scheduling of deliveries in order to reduce inventory, or can be extended to mean "pull" manufacturing (where earlier processes are triggered by later processes so that they deliver components "just-in-time" to the next process); however sometimes it means a discipline on its own, either a fore-runner of Lean or even another name for Lean, or something similar to it.

Klassen's (2000) paper is specifically about JIT and thus is mentioned here – but he takes a wider definition of JIT and so the paper covers setup time reduction and supplier relationships as well as scheduling, kanban, etc. He acknowledges a range of scope in definitions of JIT ranging from shopfloor only to holistic system, but says that JIT should be aiming to reduce waste, inventory, lead time and setup time, improve supply chain relationships and improve customer service. He found that in general the plant managers he spoke to expected to reduce pollution only by investment in pollution prevention – but on further probing they began to see the environmental improvements made by some of their productivity-improving efforts. One company had deliberately tried to integrate its environmental concerns into its Lean efforts. This is one of very few references that could be found to companies that were actively doing this, but Klassen does not give more detail about this company. As a result of the combined implementation the company reduced wastage of hazardous finishes by 50-60% at one of their plants (partly by just-in-time delivery reducing wastage of out-of-date finishes). The conclusions Klassen draws from his research are that environmental and Lean/JIT/Quality functions should be more closely integrated (these findings are discussed further in section 2.4.8 – Progress towards integration). He also notes that environmental improvement projects often led to delivery performance improvements (a sort of inversion of the "happy accident" consequences of Lean for environmental impact reduction, an idea that has not been commented on much). He gives an example of a company switching from solvent-based to water-based adhesive, which took longer to dry until they installed a microwave to "cook" the glue. This modified process reduced throughput time and produced the additional benefit of maintaining alignment of parts better, although the original purpose was to reduce environmental impact.

Womack (2005) in an opinion piece on environmental impact reduction and Lean mentions the potential positive impact of JIT, stating that companies can use milkruns to reduce emissions and traffic congestion, by reducing the number of trucks and the mileage required for their deliveries. Sarkis (2001) notes that JIT (as an improvement paradigm in its own right) has parallels with environmental improvement, noting that both require the removal or prevention of wastes, but also that JIT may increase movement and transport impacts.

Ross and Associates' case studies (2004) report environmental benefits from reducing disposal of out-of-date product due to overstocking by a JIT project to renegotiate the terms of a volume cost saving (which also resulted in larger, reusable paint storage tanks being used – another financial and environmental saving).

Discussion – **Authors identify "unintended" environmental benefits from JIT, such as reducing waste of out-of-date components, treatments, etc., reducing vehicle emissions, and reusable packaging** [I2-12]. These benefits could perhaps be made intentionally if environmental goals were introduced.

Right First Time, Quality, and Production efficiency

> *"less rework means less energy consumption"*
>
> (Sarkis, 1995, p.88)

Some researchers (e.g. Ross and Associates, 2000; Klassen and Whybark, 1999; Sarkis, 1995) note that improvements in quality and "right first time" manufacturing result in less in-process wastage and thus a reduction in the impacts associated with making, transporting and assembling components that are then scrapped

Discussion - **A reduction in failure rate could provide environmental impact reductions alongside cost saving and other production benefits** [I2-13].

2.4.7 Culture and learning style

Learning culture of the organisation

> *"Lean produces an operational and cultural environment highly conducive to waste minimization and pollution prevention."*
>
> (Ross and Associates, 2003, p.25)

All the Ross and Associates group of papers (Ross and Associates, 2000; Ross and Associates, 2003; Ross and Associates, 2004; Larson and Greenwood, 2004; Tice et al., 2005) include the finding quoted above in some form or another, and the culture change issue is discussed in some depth as a key finding in the 2003 report (Ross and Associates, 2003).

Much of the content of this section has been covered in the preceding sections as individual tools but could be included in a definition of Lean company culture (e.g. Continual improvement and worker involvement, standard work, use of metrics and goals, and a "waste elimination mentality"). One point that has not been raised before is quite how difficult companies find the change in culture that is required for both Lean and EMS implementations. Ross and Associates' researchers discussed culture change during interviews with Lean experts and representatives of companies implementing Lean and found that respondents consistently reported culture change as being one of the most difficult aspects of implementing Lean -

> *"Overcoming the inertia, skepticism, and even fear that can inhibit behavior change is typically the greatest hurdle to creating and sustaining an organizational culture conducive to Lean production and waste elimination"*
>
> (Ross and Associates, 2003, p.26)

They make the point that the cultural change of Lean is more easily internalised by companies because the reasons for doing so are more compelling (i.e. bigger financial and competitiveness gains) and the need to reduce costs and become more competitive is urgent because of economic slowdown in the US and global competition. By comparison drivers for environmental improvement are not so strong.

Larson and Greenwood (2004), in common with some of the other Ross and Associates papers and reports, comment on the similarity between Lean's culture of waste elimination, continuous improvement and employee involvement which is similar to the culture which is suggested by EMS or eco-sustainability improvement processes. They state elsewhere in the paper that the latter have not been so enthusiastically taken up, whereas Lean uptake had increased rapidly (Ross and Associates, 2003).

The culture of waste minimisation is also central to King and Lennox's paper (2001). Initially they propose that -

> *"The adoption of Lean practices may lead inadvertently to pollution reduction, may reduce barriers to implementing pollution reducing measures, or may simply provide information about the value of reducing pollution"*
>
> (King and Lenox, 2001, p.244)

Finally they find that what is important about Lean for environmental impact reduction is that Lean requires managers to accept and adopt new management styles, which they find is also important for environmental improvement programs; and Lean helps to reduce the cost of either implementing pollution prevention or of finding opportunities for improvement in processes, including environmental improvements, but they feel that more research would be required to identify which is the case.

In part two of Florida's paper (1996) he examines the results of a survey of Japanese transplant companies in the US. He finds that firms that are more innovative, use Continuous Improvement and make frequent changes to product and process design are more likely to adopt design changes for environmental impact reduction. He attributes this to a cost saving (they are already constantly making changes for operational reasons so can incorporate "eco-design" changes with these, whereas in a company with static design the changes would have to be made purely for environmental reasons) rather than to acceptance of a culture of change however – but this appears to be his line of reasoning rather than based on evidence (e.g. from interviews with companies).

A Honda of America employee on the other hand is reported as linking the company's strong environmental performance with inter-departmental involvement and responsibility for environmental impact reduction and the company culture and experience of problem-solving at all levels within the company, which was also applied to environmental problems (Maxwell et al, 1998). A review of environmental manufacturing attitudes found that at Toyota, environmental problems were approached in a similar way to other production problems, with the same dedication and attention to detail – for example, a study of energy usage in a process was detailed enough to show that a significant proportion of energy was used when the machine was idling and thus not adding value, and so the machine was redesigned. Similar projects led to the redesign of injection-moulding machines, which reduced energy usage by one-half to one-third (Gutowski et al, 2005).

Pojasek (1999) points out that mistake-proofing or poka-yoke can be used to avoid the errors that might lead to release of pollutants.

Discussion **-** Researchers using statistical methods consistently find that Lean's "culture of waste elimination" is an important parallel to environmental impact reduction programs of various types but none of them seem to investigate this aspect of culture thoroughly or make explicit what they mean by this term or how Lean achieves it. The idea that in a Lean company, a state of change is the constant state, and therefore other changes might be more easily justified is an interesting one; although it appears to be a supposition of the author based on other facts, rather than something that companies were directly asked about during interviews or surveys.

Combining the statistical findings and those from closer company involvement suggests that **a culture of waste elimination and experimentation, problem solving and improvement of best practice encouraged by Lean may help companies make environmental improvements** [I2-14].

Using Lean to demonstrate benefits of environmental improvement

Larson and Greenwood (2004) state that Lean may help "sell" eco-initiatives to the people who can make them happen and ease their introduction, and a Lean approach can help with identifying the financial case for environmental improvements. They describe an implementation at Boeing, who reduced chemical usage and hazardous waste disposal by 12%. Use of Lean tools showed them there was a business case for doing this in the savings in mechanics' traveling time – reduction in chemical usage lead to a comparatively minimal cost saving. Similarly, Ross and Associates (2000) find that -

> *"Lean thinking brings powerful financial incentives to resource conservation and pollution prevention improvement"*
>
> (Ross and Associates, 2000, p.15)

- and their 2003 report explains how the strongest financial case for an environmental improvement at one company came not from the reduction in chemical or material use (i.e. directly from the reduction in environmental impacts) but from the reduction in capital and time intensity of this production step that was effected by the improvement, and being "Lean" helped them to see and assess these improvements.

Florida (1996) used statistical methods to show that companies that have adopted Lean are more likely to adopt "eco-design". He suggests that this is because the companies are already changing product design regularly so "eco-design" changes can be implemented at the same time, thus reducing the cost.

Tice and Ahouse (2005) suggest that it is cheaper to integrate efforts to fulfil EMS objectives into Lean events than to run separate EMS events.

<u>Discussion</u> **– A Lean approach can help make the business case for environmental impact reduction** [I2-15]. Just as Lean shows businesses that they are wasting money in ways that they had not appreciated, so it shows that environmental improvements can have benefits that would not otherwise be obvious.

2.4.8 Can Lean and environmental impact reduction be integrated?

Differences and hostilities

Womack (2005) cautions that reduced prices due to application of Lean could lead to increased consumption, which leads to increased environmental impact.

Rothenberg (1990) finds that, for the best environmental performance, end-of-pipe measures are still required alongside source reduction; and that Lean companies tend to be more resistant to implementing them, because source reduction makes much more sense to them. In a collaborative paper (Rothenburg et al., 2001) she also says that Lean is statistically linked to higher VOC emissions (probably due to more frequent change-overs in the paint plants in the automotive companies surveyed, requiring more solvent cleaning and paint waste).

Ross and Associates (2003) found that it may be difficult to apply continuous improvement around environmentally-sensitive processes as the time and cost to gain approvals from environmental monitoring bodies make frequent changes untenable. This is supported by Tice *et al* (2005), who are part of the group working on this project.

Larson and Greenwood (2004) who propose a new "environmental value stream mapping" tool, note that Lean tends to focus within the four walls of the factory and maybe one step into the supply or customer supply chains, whereas environmental impact reduction requires a focus on the whole value stream, and that Lean will tend to eliminate the most (financially) expensive impacts first - although these often are the most environmentally damaging this is not always the case.

Discussion - All the authors above proposed more ways in which Lean and environmental impact reduction are complementary than ways in which they are hostile. No papers were found that came to an overall conclusion that Lean and environmental improvement were either fundamentally or practically incompatible.

Progress towards integration

As early as 1999, Klassen and Angell (1999) commented on the need for integrated research on environmental management and operations management but their literature review at that point identified some research on the integration of environmental factors with TQM (e.g. Hemenway and Hale, 1996) but none on integration with Lean.

Ross and associates (2004) comment on the need to train environmental managers in Lean, to have a cue to consult them where required especially when "Leaning environmentally sensitive processes". They also note in the same report that the five companies (operating in the shipbuilding sector in the USA) they interviewed had all made efforts to ensure that Lean changes were environmentally acceptable; either by a tollgate or checklist system which included environmental requirements, or by involving EHS representatives in Lean activities.

Vais *et al* (2006) report on integrated implementation at a Romanian paper mill but are frustratingly short on details of how integration took place; however, they do report reduction of impacts and improvement to processes. Karp (2005) reports on a supply chain project where large manufacturers nominated suppliers for assistance with profitability and reduction of environmental impacts, and again reports reduction of impacts and associated cost savings, either realised or projected.

Klassen (2000) reports that most plant managers he interviewed felt that environmental issues were important, but peripheral to their role, although he did find one company that has a senior manager with broad cross-functional experience, in charge of both quality and environmental performance. This manager felt that the combination of the two roles allowed him to provide production workers with a broader view of environmental issues, "beyond compliance". He makes recommendations as a result of his research that production managers should seek out environmental improvements from implementing JIT and that environmental managers should be trained in the implementation of JIT, and that environmental management should be integrated with production management and the two management roles should ideally both be delegated to one individual with knowledge of manufacturing.

The US EPA has a "Lean and environment toolkit" available to download from its website (United States Environmental Protection Agency, 2009), and later reports and papers (Ross and Associates, 2008; Tice et al., 2005) also show promising results from integration (detail of the methods used is provided in the preceding sections).

<u>Discussion</u> - The checklists or tollgate requirements noted by Ross and Associates are certainly a step towards integration although still a step away from actively encouraging manufacturers to search for changes that could lead to environmental improvement and operational benefit.

Inhibitors

Several researchers note two main categories of hurdles to integration – a lack of integration of environmental and production and/or quality departments and disciplines, and a lack of both seniority and understanding of production in environmental managers. For example, Theyel states that -

> *"…having a designated pollution prevention manager may not be enough, as this individual also needs to be involved in the decision making of the firm."*

(Theyel, 2000b, p.256)

Helper *et al* (1997) agree with both these points, stating that environmental managers are often inexperienced in production techniques, unable to ask for input from engineers, and too low in the company "pecking order" to have much input into strategy and decisions. This hinders the passage of environmental improvements into the company and means that those changes they are responsible for may not be the best solution for productivity. They cite an example of an environmental manager who did have production experience in a previous role and had an idea for using environmental data (amounts of waste fluid and flash disposed of) to improve quality (because worn dies produce more of both), but could not persuade senior managers to listen to his idea; and another example of an environmental manager without production experience who managed a switch from a solvent cleaner to an aqueous one, which caused problems in production due to his lack of understanding of the real requirements (which included a projected increase in throughput which the machine could not handle, and problems encountered when schedules were changed to incorporate “rush jobs” – the facility to handle these was valued by the company’s customers).

Klassen (2000) similarly suggests that environmental managers’ remits should be expanded and that there is a lack of integration between production and environmental disciplines that is problematic.

Ross and Associates (2003) predict that attempts to “paint Lean green” (i.e. to try to alter Lean’s basic aim of improving competitiveness in favour of an excessive focus on environmental improvement) would meet with resistance. Overly narrow applications of Lean tools (for example, looking only at the environmental impacts of a process without considering other production wastes such as excess movement, waiting time, and defects) could undermine the effectiveness of the Lean activities overall, including their potential to reduce environmental impacts. In a later report (2008) they noted that environmental practitioners needed to learn the language of operations staff, who needed to agree to begin a “Lean and green” implementation. Perceptions in target companies’ operations departments were often that “environmental” advisors were there to ensure compliance with environmental regulations rather than to enable improvement – consequently, practitioners had found that integrated implementation was a hard sell, even though (or possibly because) there was part-funding available for the projects.

Florida (1996) states that the biggest cost savings go to biggest polluters – the cleaner you are, the harder it is to make cost savings from further environmental improvements.

Tice and Ahouse (2005) point out that the motivations, participants and scales of Lean and environmental improvement efforts are different, which may hinder their integration.

Larson and Greenwood (2004) give three hurdles to adoption of “Eco-sustainability initiatives” – the return on investment they produce may be low when compared to other investments, the disruption of production entailed in implementation, and the reluctance of senior management to view themselves as “green” combined with the relatively lowly nature of environmental managers, who are the ones usually approached by someone trying to “sell” an environmental investment.

Discussion - These points often raise more questions than they answer and would benefit from the application of Lean’s “five whys”. Why are environmental managers so junior in most firms? Why are there so few with manufacturing as well as environmental knowledge and experience? Why are environmental and production/quality departments so separated?

The authors do not answer these questions but nor do they seem to suggest that these hurdles are insurmountable. Indeed it seems that if companies learned or observed that it makes sense to try to gain environmental and financial benefits from the Lean implementation they are already running, this might raise the status of environmental issues and remove some of the hurdles.

Larson and Greenwood’s comment on senior managers’ reluctance to see themselves as “green” is interesting. This comment, and Ross and Associates’ points about “painting Lean green”, certainly suggest that the message on integrating Lean and “green” needs to be carefully pitched, perhaps as adding value to Lean, and something that makes good business sense, but with a subtle acceptance that it is acceptable to feel good about doing “the right thing” environmentally.

2.4.9 Gaps and Originality

The intention of this research is to learn from the development and application of a method and toolkit for environmental improvement, based on the tools and methods of Lean manufacturing.

Of the key papers identified using the search method outlined in Section 2.4.1 only seven peer-reviewed journal articles could be found reporting on the results in companies of integration of Lean and environmental improvement (Jorgenson, 2008; Karp, 2005; Larson and Greenwood, 2004; Maxwell et al, 1998; Rothenberg, 2003; Tice et al., 2005; Vais et al., 2006). Given that the implementation of Lean and environmental improvement individually within companies are both complex fields, this limited number of articles suggests that action research case studies investigating integrated implementation are very likely to produce results that are a novel contribution to the field.

With respect to the first research question (If there are synergies and similarities, what are they?), some synergies have been identified in the literature, but it is possible that qualitative and particularly action-oriented research may reveal more. The second question (How can the synergies be used to inform integrated implementation?) is not covered in great depth by many authors although some theories are put forward. There is considerable scope to add to knowledge through practical implementation of modified Lean tools suggested by the synergies. The literature review discovered hardly any answers at all to the third question, which is the most action-oriented (what happens when improvements are made together?).

It was also noted that the papers found discuss neither the factors for acceptance, nor the company and workforce reactions to integration. Environmental waste is frequently claimed as a connecting factor between Lean and environmental improvement but its nature and the nature of the link, receive only cursory examination in the articles. There is scope for further discussion, and particularly for discussion in more depth, of practical methods for using the Lean tools and methods for environmental improvement.

2.5 Summary of findings from the literature review

I2-1 Lean as it is is capable of providing environmental benefits even though there is no direct intention to reduce environmental impact

I2-2 These incidental gains themselves are just as valid as “intentional” gains, but if the company is not aware of them they will not learn to look for others that do not occur as natural side effects

I2-3 The addition of environmental considerations to Lean can actually add value to the Lean implementation

I2-4 The Lean methodology can be used to make environmental improvements as well as productivity improvements

I2-5 Reduction of inventory (for example by implementing kanban) can lead to various benefits that are both “Lean” and “environmental”

I2-6 Kaizen/Continuous Improvement (CI), kaizen blitz and workforce involvement and suggestions are popularly suggested methods of gaining environmental benefit from a Lean implementation

I2-7 The ability to integrate environmental best practice into standard work could be a benefit of integrating environmental improvement with Lean

I2-8 The identification and reduction or elimination of waste is important to both Lean and environmental improvement but definitions of waste are different

I2-9 The possibilities proposed for using mapping for environmental improvement could be arranged roughly into three groups; the use of mapping to ensure a thorough understanding of the current and proposed processes; the use of mapping to identify where the main areas of (environmental) waste are; and its use to promote a holistic view (by product families rather than departments) thus avoiding “silos”.

I2-10 Goals for environmental improvement should be set, for all levels within the organisation, and communicated well

I2-11 5S schemes can result in environmental improvement side-effects and can be adapted for intentional environmental improvement

I2-12 Authors identify “unintended” environmental benefits from JIT, such as reducing wasteage of out-of-date components, treatments, etc., reducing vehicle emissions, and reusable packaging

I2-13 A reduction in failure rate could provide environmental impact reductions alongside cost saving and other production benefits

I2-14 It is the culture of waste elimination and experimentation, problem solving and improvement of best practice encouraged by Lean that may help companies make environmental improvements

I2-15 A Lean approach can help make the business case for environmental impact reduction

2.6 Conclusions from the literature review

This chapter aimed to show that the search for literature relating to the subject had been conducted thoroughly. Evidence of thoroughness was provided in the explanation of the “snowballing” method used in the search.

This search showed that there is a gap in knowledge currently provided by the literature. In particular, there were only seven peer-reviewed articles on the results of attempting to integrate Lean with environmental improvement in companies. Predominantly, the literature discusses some environmental benefits that have resulted from Lean implementations, or speculates on possible links, or a combination of the two – this suggests that there is potential for the combination to be worthwhile, but the literature indicates that there is much more research to be done to realise this potential.

Nevertheless, some interesting and useful insights into the research area were gained from close reading of the literature. Lean as normally implemented has produced environmental improvements as a "side effect" in implementing companies, although the companies do not often measure the environmental benefits – often they had not even considered them.

Lean "as is" may be seen, simplified, as a way for a company to achieve goals in improving productivity. Some authors in the "environmental impact reduction and Lean" literature speculate that it could just as easily be applied to other goals, including environmental impact reduction ones. This interesting area has as yet received little attention however.

There are similarities between the aims of Lean and environmental improvement/EMS – authors comment on the importance to both of continuous improvement, workforce involvement, waste reduction, standardising work, and inventory reduction.

Some authors speculate on the potential to use many of the tools of Lean to implement environmental improvements.

It is often stated that Lean produces a culture of waste elimination – although this statement is not discussed in very much depth – and of problem solving. Several authors comment on this area of culture, learning style, understanding and knowledge in Lean companies and its potential application to environmental impact reduction, and this seems like another rich seam that could be further explored by new research.

The literature supports the hypothesis that Lean could provide environmental benefits, but some points that refuted this suggestion and some caveats were also found. These included aspects of Lean that could increase environmental impact (for example increased VOC emissions due to more frequent changeovers in paint shops) and Lean acting to increase consumption of goods. Statistically, links between environmental impact reduction and Lean implementation were most often found to be weak, but qualitative methods showed stronger links; this could have been due to the indicators used in the statistical methods. Financially, some researchers suggest that some environmental improvement-focused “projects” can show less return on investment than other Lean projects.

3 Methodology

Chapter overview

This chapter of the thesis discusses the selection of appropriate methodology for this research.

The chapter begins with an introduction to methodology design, then follows a progression of defining the research aims and questions, then discussing and selecting strategy (including the decision to use a staged research design) and then data-gathering method selection. Discussions of selection of strategy and method are preceded by a presentation of other options considered. The next section discusses methods for validity, reasonableness and bias avoidance, and the final section discussed data analysis methods selected.

Chapter aims

The aims of the chapter are to show that the methodological choices made for this research were suitable and that other options were considered, and to explain the steps taken to reduce threats to validity, reasonableness and clarity.

3.1 Introduction

> *"The task of crossing the river corresponds to the general* research focus*. Specific* research questions *are analogous to asking how many people want to cross the river; the frequency with which they want to cross; the current of the river; and so on. The choice of* research strategy *is akin to a choice among swimming, walking, flying or sailing across. The* research tactics *(or methods of investigation) concern the particular type of boat, bridge, aircraft, etc. to be used in the crossing."*
>
> (Robson 2002, p.80 after Manstead and Semin, 1988)

Methodology and research design is an important stage of any research programme. There is a wide range of possible strategies, methodologies and data gathering methods, each with associated strengths, weaknesses and risks; they cannot be categorised as bad or good, but some will be more suitable than others for the particular research area, research questions and research aims in question. Therefore, the researcher needs to gain an overview of the options and come to a considered decision about a suitable method and research design for the research they wish to undertake.

Robson (2002) specifies the following stages of research design: selection of research focus, selection of research questions, selection of strategy, selection of data gathering and analysis method. He also gives some attention to the avoidance of bias and the assurance of reliability and validity. Each of these stages will be discussed below, followed by more detailed discussion of the chosen methods and strategies.

3.2 Selection of research focus

The research brief was broad in scope, specifying that the research must study the adoption of environmental improvement and “Resource Efficient Technologies” by companies. Initial discussions between the researcher and supervisor lead to a definite area of interest - exploration of possible synergies between Lean manufacturing and sustainability.

Provisional exploration of literature in this research area confirmed that other researchers were interested in it, the focus was most often on environmental impact rather than sustainability; some synergies and similarities had been identified, but that there appeared to be a limited number of other papers, and very few of these related to deliberate integration within companies, indicating that the research had potential value and novelty.

3.3 Selection of research questions

Based on the preliminary exploration of the research area noted above, it was decided that the research questions should focus the research on –

- further elucidating the nature of synergies and similarities between Lean and environmental improvement, because it seemed that there was still room for further research in this area;
- the ways in which these synergies might be used by companies in integrated implementation, about which some other researchers had made proposals, and a few had results of trials in companies;

- and the effects of deliberate integrated implementation within companies, about which only a very limited number of papers could be found at this stage.

It was deemed appropriate that the selected research questions might, depending on the chosen methodology and the course of the research, be subject to change, but the intention was that the variation should not be allowed to be too great. The final research questions were:

Research question 1 - If there are synergies and similarities between Lean and environmental improvement, what are they?

This may be in terms of common aims or intentions, or overlaps between the work of Lean and environmental improvement departments.

Research question 2 - How can the synergies between Lean and environmental improvement be used to inform integrated implementation?

The answers to this question will relate to tools that can be developed, and ways that integration can be achieved.

Research question 3 - What happens when Lean and environmental improvements are made together?

This question is about the effects of integrated implementation – on environmental impacts, but also on attitudes, awareness, understanding and empowerment, for example.

3.4 Selection of strategy

This section begins by reviewing some possible strategies and their relevance to this research, then discusses selection of strategies.

3.4.1 Qualitative v. Quantitative

Qualitative designs describe phenomena using mostly words, whereas quantitative designs measure them and describe the results numerically. Surveys, questionnaires and experiments are (predominantly) quantitative methods, whereas action research, ethnographic studes and grounded research are predominantly qualitative although they can use some numerical (quantitative) data as well. Using a qualitative research method can provide a much deeper, richer data set, but quantitative methods tend to be broader and more easily generalisable. There is a more established tradition of making sure quantitative research is valid and reliable, whereas qualitative methods can make some audiences nervous of their veracity; however measures do exist and the researcher can take care to plan them into the qualitative research design. (Johnson and Harris, 2002; Robson, 2002)

It was decided that the answers to the chosen research questions should be predominantly qualitative, because the research questions indicate more descriptive than numerical results, and because a quantitative study within the chosen research focus would require the participation of companies who had already attempted to integrate Lean and environmental improvement - it was considered unlikely that these could be found in sufficient numbers for a mainly quantitative method to be viable. However, it was considered likely that some quantitative data would be gathered. The research in this field includes quantitative as well as qualitative studies, for example analysis of the statistical links between adoption of certain Lean practices and reduction of environmental impact, but this research is more concerned with the potential for additions or modifications to the existing tools.

3.4.2 Fixed v. Flexible

Robson (2002) talks about “flexible” and “fixed” designs, instead of qualitative and quantitative. Fixed designs are usually quantitative, and are most easily explained using the example of a questionnaire. Each part of the questionnaire must be carefully crafted to contribute a prescribed piece of the required data. Once the questionnaire has been written, tested and ultimately sent out, it cannot be changed for that dataset (although additional different datasets could be gathered with a modified questionnaire). In a flexible design, the research design evolves in response to emerging data and may only become clear one step at a time. The researcher continually makes design changes and new designs as it becomes clear what data is required to further investigate the emerging theories. Most illustrations of flexible designs emphasize iteration and non-linear approaches (so the later stages of one iteration may lead to modification of the early stages of the next iteration).

A flexible design allows the researcher to take interesting side-tracks that are uncovered as the progressive data gathering gradually sheds light over the research territory, but in following these side-tracks the researcher runs the risk that they might tail off into nothing or lead the researcher up a “dead end”; a fixed design requires the researcher to work out a set route to a known destination in advance, with far less risk of getting lost on the way.

It was decided that the design for this research would be predominantly flexible, as the data gathered was likely to cause some changes to the design – a real world research setting and ideas that are new in the setting both made this more likely.

3.4.3 Action research

> *"Several broad characteristics define AR.*
> - *research* in *action, rather than research* about *action;*
> - *participative;*
> - *concurrent with action;*
> - *a sequence of events and an approach to problem solving."*
>
> (Coughlan and Coghlan, 2002, p.222)

Action research means that the researcher is an active participant in the research setting and may instigate change, is present while key parts of the process being researched are occurring, and observes what happens (Eden and Huxham, 1996). The researcher may interview participants, and could gather quantitative data as well. This combination of approaches gives very deep understanding of the results of an intervention from which to develop theories, but the amount of time required *in situ* and in analysing the large amounts of data gathered means that the number of cases investigated in a given time will be far less than if data were gathered using, for example, interviews or surveys (Robson, 2002).

Action research was considered appropriate for this research because the phenomenon to be studied was hypothetical and may not yet exist as an idea in the research setting; this methodology permits the researcher to observe the effects of introducing a new idea into the research setting and be an involved participant in planning and delivering the implementation.

3.4.4 Evaluation

> *"The purpose of an evaluation is to assess the effects and effectiveness of something, typically some innovation, intervention, policy, practice or service."*
>
> (Robson, 2002, p.202)

Evaluation is not necessarily research, but it can be; the evaluator tries to work out what the effects of the subject of study were, whether they are beneficial and whether they are the effects that were intended. As a result of the evaluation, practitioner oriented recommendations might be made on whether whatever was being evaluated should continue as it is, continue in a modified form, be added to, or be ceased altogether; while research oriented observations are made in parallel, concerned with what has been learnt from the study. The scope for subjects for evaluation is very broad and evaluations can incorporate other methods discussed (Robson, 2002).

It was decided that this research would not be an evaluation. The purpose of the research was exploratory, because integrated implementation would be the trial of a very new technique; the intention was to learn from implementation rather than to evaluate its worth and effectiveness.

3.4.5 Grounded research

In "Grounded theory" research the hypotheses and theories are drawn from ("grounded" in) data gathered in a given situation. Instead of starting with a hypothesis and seeking information to prove or disprove it, grounded theory looks at specific situations then seeks to draw hypotheses from the observations made. The researcher carrying out grounded research would usually visit the research setting a number of times. After each visit the data gathered are analysed, and the analysis informs the next visit. The process is repeated until "saturation" is reached (this is when the researcher judges that little new material is being found, and "surprises" in the data are very rare). Grounded research is usually associated with qualitative data but quantitative data can be included as well. Analysis is done by coding the data – looking for categories and sub-categories of data, ranges within the sub-categories, and interrelations between them. A key point about grounded theory is that it does not attempt to gather data from a representative sample of the population; rather, the researcher seeks out the situations that will best inform the research. (Partington, 2002; Robson, 2002)

A grounded theory approach was not suitable for this research because the pre-determined research aims and questions, although flexible, were too narrow for this method to be applied, and there was an intention to deliberately introduce an idea (integrated implementation of Lean and environmental improvement) into the research setting, which true grounded theory research would not do; and there was an intention to research one iteration (planning, training, implementing and reviewing) of a Lean improvement event, rather than the continuation of data-gathering until saturation is achieved which grounded theory requires.

Robson (2002) explains that Grounded theory also can mean a method of analysing data and this will be relevant to this research within the bounds of the research direction set, to allow themes and findings to emerge.

3.4.6 Case study

> *"Case study is a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence"*
>
> (Yin, 1994, p.)

The case might be a medical or legal case, or just as easily a community, organisation, person or group of people, or event. Context and setting are important. This is usually associated with qualitative data but quantitative data can be gathered as well. The amount of detail in a case study can vary according to what is required to describe the case within the selected focus. A research design might consist of one or several case studies; comparisons between cases can provide interesting additional data.(Harrison, 2002; Robson, 2002)

Robson (2002) states that in some ways all research is case research because the context (time, place, participants etc.) affect the research, and this is true of the main stage of this research; but the dominant approach is action research, as discussed above.

3.4.7 Ethnographic studies

Most readily associated with studies framed by social and cultural issues, ethnographic study methods have also been applied to operations research (Singh and Dickson, 2002). It is similar to grounded theory in that it (usually) develops theories from the data uncovered during the study (research questions and ideas about orientation might be suggested but it must be accepted that they can change as the research progresses). Ethnographic studies seek out "unusual or inexplicable study settings, working with small populations" and usually involve long-term (often a number of years) immersion of the researcher, who takes part in the group's activities in order to uncover the meaning of behaviour etc. within this setting (Robson, 2002; Singh and Dickson, 2002).

Ethnography is not an appropriate methodology for this research as the primary aim is not to study social interactions within the research setting.

3.4.8 Summary of strategy for this research

The main methodology selected was action research. This was indicated because preliminary exploration suggested this was likely to be a new idea for most UK manufacturing companies, and action research is indicated where there is an intent to initiate change and the researcher intends to participate in the change process. The action research would use the mechanism of the trial of integrated tools to introduce the idea of integration into companies, and data would be gathered during the initiation, planning, implementation and feedback stages.

It was also decided at this point that the research should follow a staged approach: a literature review, exploration stage, and an action research stage. The exploration stage would investigate how about ten companies implemented Lean and environmental improvement, and would gather their ideas and opinions on integration.

This staged approach was adopted because it would allow exploration of the research area prior to the action research, which would be especially helpful in this area because the available literature was somewhat sparse; data gathered during the exploration would inform the development of the tools; and it would allow triangulation of data-gathering methods and the gathering of data from a wider range of sources.

3.5 Considerations for action research

The main distinguishing features of action research are that it is participative (the researcher is a participant in the research setting), collaborative (the actors in the research setting are involved in planning, implementing and discussing the research) and that it is research that is grounded in an intent to change the research setting in some way (e.g. Coughlan and Coghlan, 2002) although for various reasons the intended change may not occur or may not occur as planned (Eden and Huxham, 1996) – still the research must begin with real desire for change on behalf of the host company and the action must be useful to the host company at the point of taking action. Robson (2002) comments that action research adds a fourth research aim to those identified for other research (describe, understand and explain) – this is improvement, of both the practice and of the understanding of the practice and research setting, by trying to change them.

Most authors also note the cyclic research design of action research – plan a change, act on this plan, observe the effects, and, if the change observed is not yet sufficient, plan another change with the intention of proceeding further towards the aim (McKay and Marshall, 2001). At the beginning of the study it will be necessary to do some preliminary exploration work, which occurs before entry into the plan-act-observe cycle. Baskerville and Wood-Huxman (1996) note a potential problem: the practical requirements of the problem may be achieved before sufficient data has been gathered to fulfil the research needs. This leads on to a point made in particular by McKay and Marshall (2001) and Eden and Huxham (1996), who note that the researcher may have three roles in an action research project – as a researcher, they will be concerned with the fulfiling research aims and goals and answering research questions; as a consultant, they will be concerned with fulfilling the needs of the host company; and as a participant, they will be involved in the practicalities of implementing change in the research setting. The researcher must keep in mind the need to fulfil the practical task and the need to fulfil the research aims and answer research questions, must consider a suitable method to fulfil both the research and practical needs, and must spend time on the gathering of data and on reflection, for the purpose of fulfilling research goals. This is part of the strength of action research: it can contribute knowledge that is relevant to businesses and also findings of interest to the research community, whereas other research methodologies may struggle to contribute to both (Sexton and Lu, 2009).

Eden and Huxham (1996) note that there is broad agreement that the collaborative nature of action research is important – not only is the researcher involved in assisting a group in making a change, also the actors in the research setting are involved in the research, and may contribute to carrying out the study and discussion and interpretation of results (Coughlan and Coghlan, 2002; Mumford, 2001).

This collaborative nature contributes to a richness of data because of the involvement with participants in the research setting over things that matter to them (Adams and McNicholas, 2007); the actions of these participants will affect a future that they will inhabit therefore observations may be more accurate, although the role of the researcher in helping to bring about changes that may be unwelcome to some participants may hamper acceptance (Eden and Huxham, 1996).

The element of implementing a change makes action research inherently unrepeatable, but there is an opportunity to learn from repeated iterations of the action research cycle and from comparison of research done in different research settings – however, as action research is contextual research and the starting conditions will not be the same, repeatability is not expected (Eden and Huxham, 1996).

Data gathering methods for action research can include participant observation, interviews, discussions and hard data such as reports and operational statistics (Adams and McNicholas, 2007). Coughlan and Coghlan expand on the nature of data gathering -

> *For the action researcher, data generation comes through active involvement in the day-to-day organisational processes relating to the AR project. Not only are data generated through participation in and observation of teams at work, problems being solved, decisions being made and so on, but also through the interventions which are made to advance the project. Some of these observations and interventions are made in formal settings - meetings and interviews; many are made in informal settings - over coffee, lunch and other recreational settings. In AR, directly observable behaviour is an important source of data*
>
> (Coughlan and Coghlan, 2002, p.231)

Robson (2002) notes that the same range of data collection methods can be employed as in other social research.

Some researchers comment on the desired nature of the findings or theories drawn from action research. Eden and Huxham (1996) note that findings should have implications outside the research setting, although they state that action research is contextual. Coughlan and Coghlan (2002) state that findings should be linked to observations, and that reports should be written so that the reader can test the researcher's logic in drawing the findings from the linked observable data.

3.5.1 Applicability to this research

The intention of the action research phase of this research was to introduce the idea of integrating environmental improvement into Lean implementation in the research settings. It was decided that a series of modifications to Lean tools and processes (as set out in chapter 5) should be designed as the basis for the intervention. The exploratory phase was included in the research design to inform both the development of this toolkit and the answers to the research questions.

The research was to be participative and collaborative – organisers at the host companies would help to modify the toolkit to suit their situation, the researcher would participate in discussions and in the implementation, and organisers and participants will be asked to provide feedback.

It was stated above that action research is usually cyclic. The anticipated duration of planning and implementing one iteration of the toolkit means that only one iteration will take place, although in a way this will involve several iterations of action research, as there is a constant process of modifying the next element of the toolkit in the light of reflection on the data from the previous element. The implementation will also include discussion of the likelihood of a next iteration of the toolkit within the research setting, after the researcher has exited, and the nature of any future plans.

It was recognised that the researcher would need to clarify research goals as well as action goals for each stage of implementation and this is set out in chapter 5; it was also recognised that the researcher would need to keep in mind her multiple roles as participant, consultant and researcher.

It was decided that two companies should be recruited as settings for the action research, to compare and contrast observations from each.

The researcher acknowledged the need to give rich descriptions when reporting findings, showing the evolution from observable data, to allow the reader to check the researcher's logic.

3.6 Selection of data gathering method

From sources reviewed in the previous section (Adams and McNicholas, 2007; Coughlan and Coghlan, 2002; Robson, 2002) the most useful data gathering methods for this research were considered to be observation, interviews, discussion and the gathering of hard data and documents, such as reports and operating statistics. Interviews were selected as the main method to be used in the exploratory phase.

3.6.1 Interviews

> *"We want the respondents' own perspective to emerge, explore the ways in which people working together share common understandings, get insight into particular experiences, find out*

> *motives behind decisions, get a view of informal procedures, consider apparent contradictions between attitudes and behaviour, and allow respondents time to provide their answers. Interviews seem to answer these challenges well…"*
>
> (Hannabus, 1996, p.23)

Interviews can be part of other methods, or can be a method on their own. For example, they can be a way of administering a questionnaire, a way of gathering data from individuals in a research setting for grounded research, or a way of gathering data from various research settings that will be compared and contrasted during analysis (Robson, 2002).

Interview design may be fixed or formal and researcher-led (each interview will follow the same format which is predetermined by the researcher, with the questions always asked in the same way), or may be participant-led, where the researcher simply proposes a topic for the interview and the respondent responds at will with their thoughts on the topic (Robson, 2002). There is a middle way in the case of the semi-structured interview, where there is a core of questions which are intended to gather the same data set from each setting, allowing for analysis by comparing and contrasting these answers (Hannabus, 1996); but there is also room for the researcher to follow up interesting lines of enquiry from the individual research settings, responses or interesting comments within the responses (Jarratt, 1996).

Semi-structured interviews were selected as a good method for the exploration stage of this research, to gain an understanding of a number of companies' Lean implementations and environmental improvement methods, and also to explore their thoughts about integration of Lean and environmental improvement.

In semi-structured interviews, the questions used do not need to be precisely scripted (i.e. there is no requirement to use the same wording for all interviews) but the interviewer does need to have some prompts for the information that is required from each interview and the interview design may include a structured element (e.g. a set of questions which are asked at all interview sites), which facilitates comparison of responses (Jarratt, 1996; Robson, 2002). The structured element (set questions) designed for this research is set out in chapter 4.

The questions used may be open, closed (or fixed alternative) or scaled. Open questions allow the interviewee to give whatever response they wish to a question and are often used in qualitative research. They have the advantages of being flexible, allowing the researcher to clear up any confusion over what the participant really meant and gain greater understanding of this meaning, and allow for unexpected data; but the responses can be harder to analyse and the researcher has less control over responses. Closed questions (for example, multiple choice questions) give the interviewee a range of responses to choose from and have more or less opposite benefits and disadvantages to open questions. Scaled questions are a kind of closed question but with a scale of possible answers for respondents to choose from.(Robson, 2002)

The researcher should be prepared for interviews to take considerable effort, time, and also research skills. The time and effort to deal with the multitude of data from even a small number of interviews should not be underestimated, and the researcher needs to maintain interest during the interview and be alert to the need to "probe" for more detail where this is necessary to fully understand a response (Hannabus, 1996).

Hannabus (1996) also mentions the need to be clear in communicating questions, to establish rapport, and to focus and pace the interview, among other skills, explaining that many of these are normal communication skills but may be more difficult for the researcher in an interview situation.

It is intended that the interviews will be recorded, so consent must be gained from interviewees for this to occur – it is better to state this some time before the interview in case permission needs to be granted by someone else within the company.

3.6.2 Observation

> *"…the researcher observes, notes, records, describes, analyses, and interprets people and their interactions, and related events, with the object of obtaining a systematic account of behaviour and idea systems of a given community, organization or institution."*

(Emerald group publishing ltd., 2009)

There are various subsets of observation, with varying levels of structure, participation in the research setting, and disclosure of the researcher's role – for example, participant observation (where the researcher participates in the research setting and simultaneously observes responses, behaviour etc.), structured observation (where the researcher looks for particular, pre-determined behaviours, events etc. in the research setting – this is normally part of a fixed research design) and unobtrusive observation (where the researcher seeks to observe normal behaviours in the research setting without the participants being aware that they are being observed) (Emerald group publishing ltd., 2009; Robson, 2002; Singh and Dickson, 2002).

Observation is a useful method because it does not rely on the participants' memories, unbiased accounting, or understanding of a situation (Robson, 2002) – but, conversely, it is difficult to be sure that the researcher's presence is not affecting the behaviour etc. that is being observed - the researcher should consider the effect of her presence on the groups being observed (Singh and Dickson, 2002) (in this research, groups of organisers and groups of participants being trained in Lean). The difficulty of avoiding bias due to the effect of the researcher's presence is an important disadvantage of observation although there are some mitigations in the action research methodology (see section 3.5); other techniques for avoiding bias are discussed in section 3.7.

Lee and Roth (2005) do not provide much discussion of research methods but do demonstrate the progression from observation and quotations to theories/findings.

This method will be used during the action research stage, where the researcher will in general be a participant-observer. During planning meetings, for example, the researcher would be taking part in discussion of how to implement and also observing the ideas, reactions, etc. of other participants. It was foreseen that the researcher might participate as a trainer and act as a coach during guided exercises and games, again while simultaneously observing. At other times, the focus would be more on pure observation – for example, during training sessions where the researcher is not participating directly.

Robson (2002) notes that there are options for a range of levels of structure, from structured observation, where there is a predefined schedule of behaviours etc. that the researcher must look for, to a total lack of any predefined structure. It was decided that there should be some predefined questions to answer at each stage of the action research plan (which would evolve over the course of the research), which would provide the researcher with some helpful structure, but also scope to observe and record emerging behaviours. These research aims for each section are set out in chapter 5 (pages 123 – 129).

During interviews with companies in the exploratory stage, the researcher might record observations as well as responses to questions.

3.6.3 Documents, reports and other artefacts

Various kinds of documents can be useful for gathering data in research (Adams and McNicholas, 2007), and they can be analysed in various ways. Artefacts could be such things as charts or drawings produced during exercises, or photographs taken.

Documents such as minutes of meetings, and artefacts such as charts and drawings as mentioned above, could be useful in the action research stage and would be gathered and copied if and when appropriate, but it was envisaged that interviews and observation would be the most important methods of data gathering for this research.

3.6.4 Hard data

Operating statistics, such as units of electricity used, might usefully be gathered during the action research stage and would be recorded as appropriate (McKay and Marshall, 2001) although this would not be the primary method. It was noted that there might be practical difficulties with gaining sufficiently granular measures from companies, but the research intention is to understand rather than evaluate, so precise measurement of effects is not necessary.

3.6.6 Selection of Data-gathering method for this research

This section summarises the decisions made about data-gathering for this research, in the light of the preceding discussions.

It was decided that the exploration stage of the research would consist of semi-structured interviews. This approach would provide the freedom to follow up interesting and useful side-tracks, for example when a respondent alluded to something while answering a question, or when there was some unusual aspect of the company that warranted further examination (for example, the practice of rewarding employees for suggestion schemes was uncovered as an interesting side-track in early interviews, and was a particular feature of the Lean implementation in a later company, but had not been designed into the structured interview questions). The fixed element provided by the structured part of the interviews would ensure that a core of the same questions were asked of all respondents, allowing for these responses to be compared and contrasted. Interviews were selected because they would provide some depth and some spread of data. Depth and breadth would be needed to provide enough understanding to develop the tools and to provide more confidence that the tools would be applicable to a range of companies. Data gathered in this section would mostly be respondents' responses, but might also include observation and artefacts and documents provided by the respondents.

It was also decided that data from the action research stage would be gathered by observation and digital voice-recordings would be made where possible. Where voice recording was not possible, for example during exercises in working areas of the factory, the researcher would record observations in note form. Examples of the data that the researcher might record were considered, such as decisions made and reasons given for these decisions during planning meetings, questions asked during training sessions, observation of changes made and recording data from artefacts during implementation stage (such as numbers of suggestions made, and how they are prioritised), and comments made about results or effects of the implementation during feedback sessions.

3.7 Avoidance of bias

> "Validity *is concerned with whether the findings are "really" about what they appear to be about.* Generalisability *refers to the extent to which the findings of the enquiry are more generally applicable outside the specifics of the situation studied….* Reliability *(is about) the consistency or stability of a measure; for example, if it were to be repeated would the same result be obtained?"*

(Robson, 2002, p.93)

The choice of language used to discuss the worth of research causes some debate – it is necessary to ensure that the research is of value and can be relied upon, but some parties believe that to use the terms "valid" and "reliable" attracts criticism of qualitative research, because the meanings in quantitative research are so engrained and cannot be applied to qualitative research. In, for example, a chemistry experiment, the findings might be assumed to be valid and reliable if an independent assessor repeated the experiment and achieved the same results. This is not possible in qualitative research – for example, it would not be possible for an independent assessor to go into an organisation and observe the same reactions to implementation of change once the change has already been implemented, as there are too many variables to control and the people involved would have experienced and learned from the previous implementation. In a different organisation, the different circumstances and personalities involved might provide different results – both preventing accurate repeat implantation and restricting the claims that the researcher should make about the wider application of the results from case studies. However to use other terminology might imply that qualitative research is unreliable and invalid (Robson, 2002).

This section discusses a variety of overlapping methods for ensuring that the research is of value and can be relied upon, although the terminology varies according to the authors' views on the language debate.

Robson (2002) discusses validity of description (which requires an accurate recording of what took place –voice or video recording or good notes are indicated), validity of interpretation (if a prescribed framework or theory is used to interpret data there should be openness to reviewing it in the light of the data) and validity of theory (alternative ways to explain or understand what has been observed should be considered).

Threats to validity can be from reactivity (the presence of the researcher alters what is being observed), researcher bias (researcher's assumptions and preconceptions alter their perceptions and understanding) or respondent bias (respondents modify behaviour or statements, which can mislead the researcher)

Six strategies are discussed, which can help to reduce some of the biases although they may act to encourage others –

- Prolonged involvement (Researcher spends a relatively long time in situ) Reduces threat of reactivity - researcher is more accepted; Increases threat of researcher bias - risk of researcher "going native", getting too close to the setting; Reduces threat of respondent bias - a trusting relationship should be developed
- Triangulation (…of data, observers, methodologies, theories…) Reduces threat of reactivity, researcher bias and respondent bias - if the same result is achieved in a number of ways there is more confidence in its validity
- Peer debriefing/ support (The researcher has a support group of fellow researchers with whom to discuss work completed and any problems encountered.) No effect on reactivity and respondent bias - effect is

only on researcher; Reduces threat of researcher bias - discussing findings with peers can help to highlight and thus avoid sources of bias in the researcher to which they are oblivious

- Member checking (Respondents check that the data recorded is accurate. Requires a pre-agreement on how to deal with discrepancy) Reduces threat of reactivity, researcher bias and respondent bias - respondents can explain where the researcher has misinterpreted material
- Negative case analysis (The researcher actively seeks out data that disconfirms theories - either in existing data or by collecting new data) No effect on reactivity and respondent bias; Reduces threat of researcher bias - by actively seeking out "exceptions that prove the rule"
- Audit trail (Showing your "working") No effect on reactivity and respondent bias; Reduces threat of researcher bias - by showing others exactly how and why conclusions were reached

after Padgett (1998; cited in Robson, 2002, p.174)

Other discussions of reliability, validity, quality, credibility, trustworthiness, confirmability and authenticity pick up on many of the points above but add some as well, so are worth noting in addition.

Reliability and validity are generated in qualitative research by confirmability and authenticity of interpretation – which together lead to trustworthiness. Johnson & Harris (2002) suggest that confirmability is achieved by -

- Giving transparency of approach, showing how data was interpreted and why the interpretation was the most “compelling” (audit trail)
- Multiple sets of data to back up the interpretation, “systematic confirmatory bias” i.e. multiple methods or researchers (triangulation) (however it is noted that part of the point of qualitative research is that “you can’t step in the same river twice”, which is both a strength and a weakness)
- Not ignoring cases that do not fit the interpretation (Negative case analysis)

...and that authenticity is implied by

- “Thick” descriptions – contextually rich, lots of information and insight specifically drawn from this site
- Descriptions that ring true

- Accuracy of any predictions made
- Rules for interpretation should be made specific (audit trail)
- Triangulation (of interpretation)
- Member checking

Partington (2002) gives the following guidance for credibility of grounded research

- The audit trail must include a clear explanation of the theory developed
- The audit trail must be clear, and should include, for example -
- Written case studies, each in the same form (for easy comparison)
- Summary tabulation at the end of each case study, again in the same format
- Draw together – comparison written and tabulated
- Summary models and theoretical propositions

Partington (2002) cites Miles and Huberman's (1994) list of points for judging quality of qualitative research -

- Issues of *objectivity/confirmability* (audit trail)
- Issues of *reliability/dependability/auditability*, including the clarity of research questions, of the researcher's role, and the specification of basic paradigms and analytic constructs
- Issues of *internal validity/credibility/authenticity*, including audit trail (comprehensiveness and plausibility), triangulation, negative case analysis, member checking.
- Issues of *external validity/transferability/fittingness*, including the explicit identification of informants, the diversity of cases, the consistency with readers' experiences, the thickness of description, the generic nature of processes and outcomes described in conclusions

3.7.2 Summary list of bias avoidance techniques

This researcher has drawn together the tactics that can be used to ensure validity and reasonableness and mitigate against the risk of bias as follows –

- Prolonged involvement
- Triangulation
- Peer debriefing/ support
- Member checking

- Negative case analysis
- Audit trail
- “Thick” descriptions
- Descriptions that ring true
- Accuracy of any predictions made
- Explicit identification of informants
- Diverse cases
- Generic processes and outcomes described in conclusions

3.7.3 Application of bias avoidance techniques in this research

This section provides an overview of the techniques that were selected as applicable to this research. Application of these techniques for bias avoidance in each stage of the research is discussed in more depth in the relevant chapters (4, 6, 7 and 8).

Triangulation of methods and data sources was introduced by the use of the staged design, and also by the larger number of respondents in the exploration stage. Wherever possible findings were drawn from data from more than one research stage, or more than one data gathering method, or more than one company or respondent.

Peer debriefing was used to provide a reliability check, by asking another researcher to check that they felt the findings drawn from part of the data were reasonable, and the researcher had an informal peer support network.

Negative case analysis was used throughout the research and negative cases are discussed in sections 4.5, 6.7, 7.7 and 8.15.

An audit trail was maintained while doing the research and findings are discussed from the data upwards. The researcher kept records of respondents’ names and could identify the source of all comments made. For protection of privacy of individuals and to maintain confidentiality for companies, these have been coded in any published material (including the thesis) in such a way that the researcher can identify them but the sources are not identifiable by others.

The findings drawn relate to generic Lean implementations as they might be carried out by other companies, not company-specific processes or methods.

Also, the aims of the research were selected to avoid bias. There was no pressure on the researcher to “prove that integration works” because of the research questions selected – the aim was exploration using the integration as a common setting.

Member checking was used during interviews, by sending the respondents the summary of their responses for them to check for accuracy, and during the action research by presenting the early findings during feedback sessions.

Finally, there was prolonged involvement with the action research companies.

3.8 Selection of data analysis methods

3.8.1 Exploration stage

Interviews would be voice-recorded, and the researcher would make notes during the interview of any observations made, including emphasis on particular points that might not be picked up in the recording.

The recordings would be run several times. The first run would be used to summarise answers to questions and write down direct quotations of interest. These quotations would be any points made with particular emphasis by the respondent, those which confirmed or denied emerging themes from other interviews, and those which contributed to answers to research questions or informed tool design. Subsequent runs would be used to confirm that summaries and quotations were correct and accurate, to compare against later recordings, to check for the negative case (see below) and to check for any information for summaries and quotations that may have been missed.

Summaries of question responses for all companies were recorded in a single table or matrix, to allow comparison between companies and questions.

Quotations were grouped together according to themes that emerged from the quotations themselves. It was felt that this was more appropriate than using pre-determined themes because the interview question response summaries provided a more structured seeking-out of particular information – this was a kind of triangulation of approaches to this data which would be particularly helpful in this relatively new area of research to ensure that data was not missed because its presence had not been predicted.

3.8.2 Action research stage

For each meeting or event during the action research, the researcher planned some key questions which she would seek answers to, during that meeting or event. These are explained in chapter six and seven, in the explanation of the meetings and events. The researcher also made general observations outside the scope of these questions and used quotations from recorded meetings, etc. The researcher would use the same methods as used in the interviews for selection of observations and quotations, and analysis of recordings; quotations would also be useful in reporting the research findings, as part of the trail linking observations and findings back to the original data.

3.9 Conclusions

Chapter three explained the methodological choices made for this research.

The chapter began by explaining the importance of methodology selection to research.

Next, the selection of research focus (exploration of possible synergies between environmental impact reduction and Lean) and questions (If there are synergies and similarities, what are they? How can the synergies be used to inform integrated implementation? What happens when improvements are made together?) were discussed.

Methodological options were reviewed and the choice of primary methodology (action research) was explained, then this methodology was discussed in more detail, and implications for this research of the points discussed were set out.

Data-gathering method options were reviewed next, and the choice of methods explained – it was decided that interviews with a range of companies would be used to gather information in order to design tools to use as the basis for action research, and also to contribute to answers to research questions. Observation would be used during the action research, and documents, reports and measurements / operating statistics might also be used.

To avoid bias and ensure the research could be considered to be valid and reasonable, the researcher would use triangulation, peer debriefing, member checking, negative case analysis, audit trails, thick descriptions, descriptions that ring true, accuracy of any predictions made, explicit identification of informants, diverse cases and generic descriptions.

Finally, analysis methods were discussed, and this section explained that emerging themes would be important in analysis of data from this research.

4 Exploration stage interviews

Chapter overview

This chapter of the thesis explains how the exploration stage interviews were carried out (including interview questions / design) and presents the interim findings from this stage.

The chapter begins by explaining the interview method, then discusses company selection criteria and methods and the profiles of companies that took part in the interviews.

The main body of the chapter presents the findings from the interviews organised by themes that emerged during analysis of the interview responses. For each theme, quotations relating to that theme are presented, then a discussion of the relevant data. Key findings for the theme are highlighted.

The key findings are then summarised in a separate section, grouped together according to the research question whose answers they inform. Negative cases are discussed and presented. Finally, the chapter conclusions are presented, showing how this chapter fulfilled the aims presented below.

Chapter aims

The chapter will explain how the interviews proceeded, the data and findings gained from them, and how they can be interpreted. The chapter will show that the data summaries are accurate and that the findings are reasonable (i.e. that another researcher might reasonably have been expected to draw the same conclusions from the data), and will point out how bias was avoided at each stage. It will also present and explain any data that disagrees with the emerging patterns or contradicts other data or findings.

Notation used

Quotations are referenced in the format [company, respondent, reference number or time] where reference numbers are allocated to quotations from tape recorded interviews in order of appearance in the interview, and company and respondent indicators are as given in figure 4.2. Interim findings from the exploration stage interviews are referenced in the format [I4-x] where x is the order of appearance of findings within this chapter.

4.1 Introduction to the interviews

The aim of the semi-structured interviews was to find out more about the companies' Lean implementations, sustainability improvement and environmental impact reduction efforts, the effects of Lean on sustainability / environmental impact reduction in their implementation, what they thought about the similarities between them, and their thoughts on the use of Lean tools for sustainability and/or environmental impact reduction. The interviews were also intended to provide data to inform the building of a trial toolset to use as a basis for these case studies.

The interviews were semi-structured to gain a common core of data from each company, allowing for comparison between them, but also allowing the researcher to follow up interesting sidelines that occurred during the interview and were unforeseen when designing the structured questions.

4.2 Interview method

4.2.1 Company selection criteria

Selection of companies to take part in the exploration phase was limited only by the fact that all companies were to be engaged in manufacturing, and that the majority at least needed to have some experience of implementing Lean. Only manufacturing companies were selected because it was felt that carrying out fact-finding in more than one area could lead to less cohesive data; the maturity of Lean in the manufacturing sector (although it is being applied in other areas with some interesting results), and the researcher's experience in manufacturing, suggested this was the most sensible sector to focus on. It was specified that companies should have been implementing in some form for at least a year, to ensure that they could talk about the experience of implementing Lean as well as their plans for future implementation. Beyond this it was felt that it was not necessary to restrict the selection any further, and that to do so would cause added difficulty in recruiting companies.

Companies were approached via the researcher's previous work contacts; current colleagues, supervisor and other researchers; or those who had written articles or given presentations about their company's Lean implementation.

Whilst arrangements for the interviews were being made, it was explained to the participants that the information required for the research was on both Lean and environmental impact reduction / sustainability activities, so either one respondent who could answer questions on both issues was required, or a number of respondents. In most cases two people attended, either together or separately, and these were usually the operations director, engineering manager or a senior member of the dedicated Lean engineering team, and the Environment, Health and Safety (EHS) Officer, EHS Manager, or Environmental Officer.

4.2.2 Interview design

The core interview questions are presented as a table in Figure 4.2, along with the reason for inclusion of the question (or in other words, what information it was hoped would be gained by asking them) although it should be noted that it was intended that taken as a whole the questions would give a picture of how companies implement Lean and environmental improvement.

With the exception of the first interview, where there was a technical problem with the recording equipment, the interviews were voice-recorded (with the interviewees' permission) and some brief notes of answers were made at the time as well. Interviews with companies B, C and D were voice recorded using a tape recorder and the remainder were digitally recorded, which allowed quotations drawn from these later recordings to be referenced by time within the interview. Interviews B, C and D were transcribed and notable quotations were highlighted and numbered in order of occurrence.

Please note that sample transcriptions of interviews are provided in Appendix A and tabulated summaries of responses from each company and summaries arranged by question are in Appendix B.

4.2.3 Bias avoidance

Section 3.7 (Methodology chapter) presents techniques for avoidance of bias that will be used at various stages in the research. This section explains which of these were applied in the interviews, and how.

Where possible, findings were drawn from three or more sources within the interviews; however, as the interview findings are interim findings which will

Figure 4.1 – Table showing interview structure

Question to ask in interview	Reason for the question
	Lean questions
What instigated your initial interest in implementing Lean?	To explore the motivations for companies adopting improvement programmes and extrapolate what might motivate them to adopt "environmental impact reduction and Lean"
When did you start your Lean implementation?	To understand how mature the implementations are likely to be
Was your expert in-house or consultant?	To find out how companies like to get information
Did you use a recognised Lean implementation plan, or choose the tools that fitted your needs best?	How much prescription do companies like at various stages of implementation? What implementation plans are popular? If they pick their own route, how do they choose tools? Are they inclined to pick those they can implement easily, or those that help to fulfil a need or solve a problem?
Please can you briefly describe the structure of your Lean implementation?	What do companies mean by Lean? How do they apply it and how do they make it work for them? Leads to ideas about how "environmental impact reduction and Lean" might be operationalised.
Which Lean tools do you use?	What is particularly popular / works well? These might be good tools to base the new ones on.
What were the financial benefits you observed?	Are they highlighting any financial benefits that are also environmental benefits? "environmental impact reduction and Lean" would need to maintain these benefits and preferably add to them. Another indicator of how Lean "works" in practice.
How do you measure these?	What good ways to measure are mentioned? Are the benefits actually measured or just estimated?
Can you identify why they occurred, and at what stage?	Is there any tool, method, etc. that is particularly "successful" in terms of financial benefits?

What other changes did you observe - more in the way that you run your operation, in your processes and procedures, that kind of thing?	Helps to understand what they've actually done. Where might there be sustainability benefits? How does their implementation work? What was the main focus of their implementation?
Do you see Lean as a one-off project, or something you will continue to do for the foreseeable future?	Is this a permanent change? Are companies thinking in terms of improvement projects or a fundamental change to the way they do business?
How Lean do you think your company is today - say on a scale of 1 to 10, with 10 being "perfection" and 1 being "not at all Lean"	Deliberately not given a definition of the scale! The number is not that important, the explanation of it is more interesting – what constitutes Lean maturity for them? What would be "perfection"? What are they working towards?
There appears to be no 'one truth' about what Lean is. Can you say, in one sentence, what are the principles that make up Lean for you?	What is the main focus for Lean in companies? What do they mean/understand by Lean? What key elements would have to be included in "environmental impact reduction and Lean" for it to be recognisably Lean?
Environmental	
How sustainable / environmentally friendly would you say your company is? Say on a scale of 0 - 10, with 0 being totally "unfriendly", and 10 being perfect?	Again it's the explanation that is more interesting in this question than the actual scoring. What are they aiming for? What would score 10?
What do you think are the main effects of your operations on the environment? What about social impacts?	How aware are these companies of their impacts? What are the most "popular" major impacts (acknowledging that this is only a small sample)
How did you work out what your main impacts are and decide what improvements to make?	What methods are commonly used, do they think they're reliable? Do companies have access to means of assessing their impacts (esp. smaller companies)? Are they measuring, assessing or guessing?

What (if anything) are you doing to reduce your impact?	How are they organising their environmental improvement initiatives at the moment? Any evidence of measures, monitoring, CI, workforce involvement, etc.? Any particularly good ways of doing this that could be learnt from?
What have you found most difficult during your efforts to become more sustainable?	What do companies need most help with? (Therefore "environmental impact reduction and Lean" might attempt to help with these aspects). Is it "hard" to implement environmental improvements?
Is environmental improvement a cost or an opportunity to your company?	Does "Leanness" affect this perception? What is the majority view? Reasons are also interesting. If they see it as a cost, are they predominantly looking at "end of pipe" reactions to pollution rather than avoidance at source?
Have you followed any environmental or sustainability improvement implementation paths e.g. ISO 14001, EMS, natural step?	Are any of these popular and worth learning from? Any particular reasons for popularity or lack thereof?
Lean and environmental improvement	
As a result of your Lean implementation, did you observe any of the following…. reduction in energy usage, reduction in waste, increase in sale / reuse of waste …?	Does this back up the findings from the literature? Add to them? Present new ideas about synergies? Have respondents thought about this, measured changes?
As a result of your Lean implementation, did you observe any of the following…. increase in energy usage (on site), increase in transport miles… anything else that you feel made your company less sustainable / environmentally friendly?	What causes negative impacts and can it be circumvented?

The aim of this project is to use Lean tools and adapt them to increase their sustainability / environmental impact reduction benefits - what are your thoughts on this idea?	This is a sense check, also a way to generate new ideas about synergies. What are the respondents' attitudes after discussing the idea?

be drawn together with findings from the other stages, this rule was not strictly adhered to where it would mean the omission of a finding that could potentially be useful when corroborated with other data during final synthesis.

Peer debriefing was used by asking a fellow researcher to listen to two randomly chosen interview recordings and check that the summary question responses were reasonable (i.e. that he would have summarised them similarly). The research supervisor was also asked to do a similar check using an interview transcription. Throughout the research the researcher had a variety of sources of support and venues for discussion with fellow researchers.

Member checking was carried out by sending response summaries to participants, giving them the opportunity to check them for accuracy of interpretation.

During analysis, the researcher looked actively for any data that disagreed with or modified the findings or emerging themes. This is presented in section 4.5 below.

An audit trail was maintained while doing the research by keeping notes and recordings on interviews and interactions. Findings are discussed from the data upwards, comparing findings from different companies and with quotations from respondents, to allow readers to decide for themselves that the findings are reasonable.

The researcher kept records of respondents' names and could identify the source of all comments made. For protection of privacy of individuals and to maintain confidentiality for companies, these have been coded in any published material (including the thesis) in such a way that the researcher can identify them but the sources are not identifiable by others.

Ten companies were interviewed in order to give some diversity of company situations and respondent viewpoint. By the tenth interview there was some repetition of key points across the ten companies and some variation, but the main themes remained the same, indicating that there was some diversity of selection but enough companies had been interviewed to give a good range of views.

4.2.4 Analysis method

To carry out analysis of the digitally recorded interviews, the researcher firstly listened to the interviews several times over, summarising answers to questions the first time, then on subsequent listening sessions checking the summary answers and listening for quotations. Quotations were selected because they supported emerging themes or contradicted them, presented new and relevant ideas or information that might be the initiator of a theme, or were particularly strongly or emphatically expressed or given high importance by the speaker. The quotation reference was noted along with the reference, in the format used within this chapter – see chapter overview – Notation used, above. Interview response summaries were sent to interview respondents for member checking and any errors of understanding they reported were corrected.

Once the interviews were complete, the question responses were compared and contrasted and an overall summary created. This summary collated responses that agreed and pointed out those that disagreed, and the proportions of companies in each group. Quotations were grouped together by themes that began to emerge from consideration of the responses to questions and the quotations, and these formed the basis for the structure of section 4.4 of this chapter.

4.3 Respondent company profiles

The ten companies interviewed were identified by allocation of letters A-J, in the order that they were interviewed. The table in Figure 4.2 provides some background that may be relevant to the companies' interview responses, gained during interviews, from the companies' websites (these are not referenced to protect confidentiality) or from business directories. Please note that the lengths of time implementing Lean are given up to the point of interview.

Figure 4.2 – Table of company and respondent profiles

	Size	Lean experience	Other relevant facts	Respondents	Circumstances of interview
A	SME, part of a larger group, which is in turn part of a multi-national	First started in 1996 (using some tools but fairly unstructured). Began in earnest 2002	Make small components for sale business to business. Mostly bench-top assembly, little automation.	Operations director (A) Manufacturing systems manager (B)	Interviewed together. Paper notes only due to tape failure
B	Over 1000 employees on site at which interviews carried out, part of a larger group, which is in turn part of a multi-national	3 years (but has changed radically within that time and been relented several times)	Make large products for sale business to business and to consumers. Predominantly automated or semi-automated manual assembly and some fabrication, painting etc.	Operations director (A) Environmental manager (B)	Interviewed separately, recorded on tape
C	Large enterprise – part of a larger multinational group.	Three and a half years implementing Lean on their site	Materials processor	Operations Director (A) Lean manager (B)	Interview with Lean manager, operations director present for initial discussion. Recorded on tape (some tape errors) and transcribed
				Environmental manager (C)	Sent questions to respond to on paper
D	SME, part of a larger	About 3 years	They make small components,	Lean manager (A)	Interviewed Lean questions

	Size	Lean experience	Other relevant facts	Respondents	Circumstances of interview
	multinational group		selling business to business in the automotive sector.	Environmental, Health and Safety manager (B)	A only, rest together, Digitally recorded and transcribed (see appendix A)
E	Large enterprise, part of a larger group	Over 25 years	Consultancy, based on experience of Lean in-house.	Lean manager (A) EHS representative (B)	Interviewed together
F	Large business, part of a multi-national group.	Around 5 years	Manufacturer of large equipment, sold business to business. Fabrication and assembly.	Operations director (A) Environmental, Health and Safety manager (B)	Interviewed separately
G	Large business, part of a larger group	Initiated about 10 years ago	Manufacturer of large products for the avionics industry, sold business to business	Lean manager (A) Environmental manager (B)	Interviewed together
H	SME, privately owned (not a plc)	About 5 years	Make small components. Bench-top assembly and fabrication, some automation	Operations director (A)	Interviewed – responsible for Lean and EHS
I	Large business, part of a multi-national group	Just over 2 years	Manufacturer of small electronic components.	Lean manager (A) EHS manager (B)	Interviewed together
J	SME, part of a larger national group	About 2 years	Vegetable processor. Some automation.	Group operations manager (A)	Interviewed together

	Size	Lean experience	Other relevant facts	Respondents	Circumstances of interview
	group			Site operations manager (B)	

4.4 Discussion of findings from the interviews

4.4.1 How do companies implement Lean?

> *"an all encompassing system that's trying to, as efficiently as possible, turn a raw material into something the end consumer wants"*

[Company E, respondent A, 1h12m]

> *“The main principles of Lean for me are – there are 5 that I cover in my induction. Basically they cover it all – understanding value from the eyes of the customer; and you need to understand your own value stream; and how that value is then flowing through your value stream to the pull of the customer while seeking perfection. The other thing that we say, in a nutshell, is it’s making what the customer wants when the customer wants it. No more, no less.”*

[Company D, respondent A, 49m]

> *“Sustainable improvement in either people’s quality of their working life, or in the benefit to our customers, or profitability of the organisation. I put them in that order, but philosophically people should come to work and enjoy their work, we want to make it an interesting place to work. If you make it an interesting place to work, then customer satisfaction is typically high on the agenda, in my opinion. If you have happy customers they’ll come back and order again from you, so therefore it will carry through to your profit. If we are an easy company to do business with, because we have simple streamlined processes that are clearly understood by all our employees, and not bureaucratic or complicated, then customers typically do business with people because of ease of business”*

[Company F, respondent A, 28m]

The responses to questions five, twelve and thirteen showed that the ways in which respondents defined and applied Lean varied substantially from company to company. This variation in the answers suggests that there is no one right way to implement Lean. Although this might reflect varying depths of understanding and different Lean maturity (i.e. some of the variation is due to better or worse implementations) it seems probable that part of the variation reflects companies adapting Lean to suit their particular situations and problems. As a result, **the tool-set should be designed to be flexible** [I4-1] as far as possible. This section of the thesis will draw together the responses on what Lean means to the interview respondents and how their companies implement it.

Question 14 asked Lean respondents to give one or two sentences on what Lean means to them. This was a free response question rather than a multiple-choice or selection from a list of common components of Lean definitions, so there was a need for some interpretation of responses to group them into common themes. From ten companies and eleven Lean respondents interviewed, eleven themes were identified, with most respondents giving several key features, and eleven features being referred to by more than one respondent.

Respondents from companies C, E, F, G, I and J all talked about some form of efficiency improvement, where efficiency is some combination of a reduction of Lead time (companies C, E, G I and J mentioned this), cost (F, G and I) and inventory (C and I) and an improvement in quality (G, I and J).

Companies B, E, F and J all discussed issues of workforce involvement, culture, and improving the quality of working life. Three companies mentioned the latter in some form (E, F and J) and they all discussed a need for the workforce to be working comfortably rather than rushing to complete work as fast as possible.

Companies A, D, E, F and I all mentioned waste and/or value in their responses to the question, often clarifying that this was value to the customer.

Companies D, E and J mentioned some aspect of levelling flow and/or pull in their responses.

Two respondents (from companies B and E) mentioned the Lean tools as a group in their responses, but in both cases this was in the context that they were less important than cultural and other issues.

Respondents from three companies (A, B and D) talked about optimisation of processes or the pursuit of Perfection, and one (from company F) about the need to develop simple processes that are easy to understand, explaining that this would be noticed by the customer (see quotation above - [Company F, respondent A, 28m])

Company E's respondent commented on the holistic nature of Lean, explaining that it should be a way of doing business and not restricted to purely manufacturing, and that it should extend outside of the four walls of the company, back to raw material extraction and forward to the customer.

Company A's respondent said that it was about continuous improvement.

Finally, company E's respondent said that it was important to Lean that it was about doing things, rather than just talking about them, and company H's respondent said that Lean was about doing the right and sensible things.

Question 6 asked respondents to identify which tools (from a list) they used in their implementation, giving the option to add other tools they used which were not on the list. Figure 4.3 shows the most popular results.

Figure 4.3 – Table of tool adoption rates among interviewed companies

Tools	**Number of companies**
5S, Kaizen/CI, Poka-yoke, value stream mapping	10
"Pull" systems, Root cause analysis, single piece flow, TPM, Value/*muda*	9
Takt time, Visual control, kanban, Cellular manufacturing, Kaizen blitz	8
JIT, SMED, Smoothing, Two-bin	7

Of the tools attributed with potential to reduce environmental impacts by the "environmental impact reduction and Lean" literature, 5S, Continuous Improvement and Value Stream Mapping are used by all companies, root cause analysis is used by nine, visual control, kanban, and kaizen blitz by eight and Just In Time by seven. Company H's respondent identified some potential in SMED, which is used by seven of the companies. Single-piece flow can reduce inventory and scrap, which is also a theme that emerges from the literature regarding side effects of Lean for environmental benefit, and it is used by nine of the companies. From responses to other questions and observations during factory tours it was clear that all but one of the companies used some form of auditing (for example regular 5S audits) and had clear goals, and several used goal deployment although they did not always call it by this term – but these were not very common additions to the list.

It was noted during the interviews that most respondents did not place much emphasis on Lean tools except while responding to this question – for example when describing their implementation in response to question 5, they did mention tools such as mapping, kaizen blitz and 5s, but spent longer talking about training, goal setting, prioritising areas to work in etc. Therefore, it is suggested that **the adapted tools should not be the sole focus when explaining integration of environmental improvement with Lean** [I4-2].

Given the variation in what Lean means to companies, and the tools that they use, it is not surprising that the structure that they used also varied although there were some common themes. It seems that most companies like a kind of "flexible guideline" for their implementation, as few had done without any framework at all, and few had stuck rigidly to a prescribed formula. Despite the widespread distaste for consultants, most companies were roughly following an implementation plan provided by an external agent, although a couple of companies said they had just implemented tools as and when they were appropriate or needed.

There was a definite sense of evolution of Lean programmes in most of the responses to this question – it seemed that their approach to Lean had matured as they gained experience and hence the direction of implementation had changed (although they did not say this directly but rather implied it).

In general the responses implied that most of the companies like to implement in a defined and manageable area, either searching for all the problems in that area or acting in an area because they have identified a problem whose source is believed to be in the selected area, and there would most likely be some sort of "blitz" event to start Lean off in an area. A way to prioritise is useful and some kind of structure is desirable, although this should not be too rigid. Some form of mapping is often used although the motivation varies. Most companies had some form of suggestions scheme to capture ideas generated by the workforce during and/or after the initial burst of Lean activity in an area. These are all discussed at a later stage in the chapter.

Goal setting, Continuous Improvement, Mapping and blitz events should be considered for adaptation for environmental improvement because they are common elements of Lean implementations [I4-3].

4.4.2 How do companies make environmental improvements?

Interviewed companies' environmental improvement programmes were perhaps even more varied than their Lean implementations. Questions seventeen and eighteen discussed how companies assessed their main environmental impacts and prioritised environmental improvement actions, and what efforts they had made to reduce their impacts, respectively, and these shed the most light on environmental improvement practices.

Half of the environmental respondents interviewed were aware of having done any kind of quantitative analysis of their companies' main impacts in order to guide their environmental improvement programmes and prioritise actions, and a further two monitored various environmental measures. One of these had done an LCA exercise, although the respondent questioned the validity of this. Of the remainder, the representatives for two companies had used reasoned assumptions based on their knowledge of the companies' activities, and others prioritised potential causes of non-compliance, costly impacts, or customer requirements.

On actions taken seven of the ten companies discussed energy saving measures, and five were sourcing or generating "green" energy or investigating doing so. Waste reduction and the segregation of waste for recycling or reprocessing were also popular. Three companies mentioned awareness programmes and staff training, particularly on simple energy-saving measures such as switching off lights etc. when not in use

Three respondents said they were using reusable packaging or investigating its use. A further three had made substitutions of more environmentally benign products or materials for more environmentally damaging ones, for example using water-based paints instead of solvent-based ones.

Two companies were pursuing waste reduction or zero-waste programmes and the same two were looking at designing products that had reduced environmental impact, or redesigning existing products to reduce their environmental impact. Another two companies were reducing the amount of consumables they used – one specifying “chemicals” and the other lubricants.

Individual companies were implementing a variety of environmental improvements and these were: reducing the range of materials held (see quote at the head of this section); measuring energy usage by department and giving the departments goals for reduction; reducing stocks to reduce risk of accidental release of substances and waste; reuse of material used for purging injection moulding machines; generally trying to use materials more efficiently; a policy of using only recycled paper; a paperless office policy (the company had tried to implement this but not been successful so far); Implementing product service systems (the main benefit of this was the ability to recover materials from old products for this company); and end-of-pipe treatment of effluent.

4.4.3 Integration of Lean and environmental improvement

Current level of integration

> *“They’re actually using Lean tools to map, track and identify areas of improvement in our waste streams”*
>
> [Company J, respondent B, 1m]
>
> *“We communicate so well, there’s always the opportunity for someone like* (environmental manager) *to say, by the way guys, have you considered the impact on… from what you’re doing?”*
>
> [Company I, respondent A, 1h46m30]

In general companies did not integrate the Lean and environmental departments [I4-4]. Only one of the companies interviewed (company J) was making particular efforts to integrate Lean and environmental improvement, aided by having an operations manager who was particularly interested in improving the company’s environmental performance. As the quote above shows, company I felt that although there was no formal integration of departments, there was good interdepartmental communication and therefore good awareness and a chance to make suggestions to other departments.

In three other companies (D, E and G) the environmental staff clearly had a good understanding of the Lean implementation. In one company (H) the operations director was in charge of both the Lean and environmental functions, and in a further one (company F) the operations manager displayed a good understanding of company environmental impacts and impact reduction, but most of the Lean representatives interviewed had little knowledge of their company's impacts. One environmental representative (company C) stated strongly that he was unhappy with the lack of cooperation between the Lean and environmental functions.

Responses to the concept of integration

> *"Does Lean and sustainability go together? Absolutely. But I'm not going to get evangelical about saving the planet. It's about eliminating waste and doing the right thing in the right place at the right time".*

[Company B, respondent A, #27]

> *"SMED as well… that whole analysis of each little thing you do that goes into the big thing and then questioning why you do that – why don't you make that easier to get to? Or eliminate it completely by doing something else… you could then apply that to how you are using electricity…"*

[Company H, 2-47m]

> *"I think it's really important that we work together and learn the tools, because I think we should be in a position where we're doing them almost without thinking, it should be part of the normal consideration when we're doing improvements. When we're changing a cell or implementing a process or product line, it should form a part of the philosophy."*

[Company D, Respondent B, 1h46]

> *"One of your questions is about linking Lean and environmental sustainability and I think there's a lot that can be done and I think the two can potentially work closely together but it is all around intent"*

[Company E, respondent A, 46m)

> *"Eminently. The question… …is very pertinent and there is without doubt, and it's really by way of application, a direct correlation between Lean manufacture and environmental considerations."*

[Company F, respondent B, 3-55m]

Comments on the idea of integration of the concepts, once it was proposed for discussion, were generally positive [I4-5].

As well as the comments above, respondents from companies A and H both stated that they had at first found the idea of integration a little strange, as the two concepts had not at first appeared to be connected. However, once they had had chance to discuss synergies give the idea more thought, they felt that it did make sense to them.

The main exception was company C's environmental respondent, who stated in response to questions 22-24 that he did not see any sense in integrating environmental improvement into Lean, and that a Life Cycle Analysis program would make more sense. This respondent had by necessity been sent the environmental improvement and integration questions as a questionnaire to fill out, so had not had this chance to discuss the synergies, which may or may not have affected the answers he gave.

Lean and environmental definitions of waste

> *"if you wanted to bring the environmental side in you could expand on the waste elements. We could quite easily do that in what we're doing today"*

[Company I, respondent A, 1h25]

> *"we don't* (add environmental wastes to the Lean wastes) *because we've said no, there's seven wastes. I've read that you can add all the environmental ones if you wish, and to be honest it's a good idea sitting here thinking about it now, to do that, because in terms of the people in the business it would be new opportunities for them, to start thinking about more improvement opportunities"*

[Company I, respondent A, 1h58m]

> *"…One of the things I think about on environmental impact is if you can take a supply chain and improve its effectiveness… … so in those stats about value-adding and non-value-adding, it's commonly believed that 70% of the resources consumed in any business are non-value-added…"*

[Company E, respondent A, 1h17]

> *"There's a link – reducing waste, for example energy usage leads to a reduction in the cost of compliance and environmental damage"*

[Company B, respondent A, #24]

A respondent from company I said that he could see the benefit of adding environmental waste to Lean's list of wastes, but that the corporation had decided to stick to seven wastes so this would be quite hard to do. He also stated that ISO 14001 and Lean are similar in that they both have

> *"the same kind of principles of reducing waste…"*

[Company I, respondent A, 4m]

In the quotations above, the respondents are stating that **both Lean and environmental improvement are concerned with waste** [I4-6], and also that **there are environmental impacts within the Lean wastes** [I4-7].

Synergy

> *"I'd say they* (Lean and environmental improvement) *go hand in hand actually, I wouldn't think you could do one without the other"*

[Company C, respondent B, #22]

> *"you can actually say anything we do in the factory that's going to have an impact on water use, we need to be considering these issues now, not at the end of the job."*

[Company D, Respondent B, 1h45]

> *"I think it's really important that we work together and learn the tools, because I think we should be in a position where we're doing them almost without thinking, it should be part of the normal consideration when we're doing improvements. When we're changing a cell or implementing a process or product line, it should form a part of the philosophy."*

[Company D, Respondent B, 1h46]

> "…(a packaging improvement project) *came out of Lean originally, but then it kind of got lost, and it then came under the arm of environmental department – it started off under the banner of standardisation"*

[Company I, respondent B, 1h44]

In these quotations, respondents are discussing the way in which Lean and environmental improvements can affect each other, and the potential benefits they predict from considering both Lean and environmental criteria when making changes, to avoid having to go back and address problems afterwards. The quotations suggest that **companies can save effort by considering possible environmental impacts while planning Lean changes** [I4-8] rather than dealing with them once the change is already in place, and **Lean ideas should be considered while making environmental improvements** [I4-9].

An extension from this, which is also stated in some of these quotations, is that **it would be beneficial for environmental and Lean departments to work more closely together** [I4-10]

Environmental side-effects of Lean

> *"As part of Lean there's obviously lots of little things that have been done as a result of getting in people's minds taking waste out of processes – simple things like going into areas where there's one switch that controls lighting for say a whole office and he said, "well why can't we have it so there's a switch for that one, a switch for that one" – it's more controllable and we're using less power, less lighting and it's got that kind of thinking into people's heads. There's probably lots of little things that are being done – lots of them. It's a shame you can't pull them all together and see the overall impact"*

[Company I, respondent B, 1h36]

> *"One of the things I think about on environmental impact is that if you can take a supply chain and improve its effectiveness and we've got examples of it, you can take out whole warehouses you don't need with all the associated environmental impact of that whole warehouse and energy…"*

[Company E, respondent A, 1-1h17m30]

The interviews confirmed that **there are environmental improvement side-effects from a standard Lean implementation** [I4-11], but it was also noted that **most companies found it hard to be certain of the environmental impact of their Lean implementation because they did not intend to make environmental improvement and thus did not measure it** [I4-12].

Question 22 of the interview asked respondents whether they had observed any environmental improvement as a result of their Lean implementation. It is worth noting that the lack of integration discussed above meant that respondents found it difficult to give a complete and accurate list of the environmental effects of their Lean efforts, as few had environmental measures incorporated in the way they assessed the success of Lean endeavours (representatives of three companies stated this specifically, and only companies E and J mentioned having incorporated Lean measures), and environmental staff were not always involved in or aware of the detail of Lean endeavours.

The two most popular responses were packaging reduction and scrap or waste reduction. Five companies had reduced the amount of packaging used, either by rationalising packaging procedures, using reusable packaging (introduced for Lean reasons, because of the long-term cost-saving and also because it allowed optimisation of packaging design for easier handling and access to products in assembly and/or provided better protection thus reducing damage to products), or reusing cardboard packaging. Five companies had also seen a general reduction in scrap and other waste. Some of this may have consisted of reductions in waste to landfill due to better waste segregation. One company had reduced the amount of material in its products and one had redesigned a component so that it could be made using a different material and process in order to reduce the process time from 20 weeks to 1 week, with the beneficial side effect of using a more benign material with less processing waste and what waste there was could be reprocessed in-house.

Two companies had seen reductions in the electricity used per product as a result of Lean and two had seen energy reductions made as a result of Lean CI suggestions (see quotation from company I above). One respondent observed that simplifying process flows meant that whole processing stages could often be left out, which he presumed would generally result in lower overall energy usage per product. Similarly, one company had rationalised the duration between cleaning in one of their processes, and realised that they did not need to clean so often, reducing the amount of solvent cleaners they needed to use.

Three companies had seen environmental improvements due to some kind of redesign of their workplace – one by eliminating the need for a number of warehouses, one because Lean had enabled them to get more production capacity in the same space and without an increase in use of electricity etc. proportional to the increased production, and one by factory redesign.

Finally, one company noted that being Lean had almost certainly helped them avoid the need to take production to lower cost economies overseas, therefore reducing the impacts of transporting their product back to the UK and the potentially higher impacts incurred through working where impacts are less tightly controlled.

4.4.4 Cost saving / efficiency

When answering question one (What encouraged your initial interest in implementing Lean?) six out of ten companies gave answers relating to cost saving. Interestingly, only one of the ten replied that there was some kind of imperative to take action to become more efficient, such as imminent bankruptcy, that meant the perceived risk of implementing Lean was less than that of doing nothing (often called “the burning platform”).

One respondent, in answering question 24 (what do you think are the synergies between Lean and environmental improvement?) felt that the main link between the two was cost.

During discussions of the environmental improvements they had made, companies commented on the cost savings they had made while making environmental improvements.

The implication from this is that **the integrated tools should maintain the emphasis on cost saving because this is an important element of both Lean and environmental improvement for companies** [I4-13]; also **it is not always necessary for there to be a financial or other imperative to adopt Lean; companies will adopt simply out of a desire to improve** [I4-14].

4.4.5 Lean themes and tools and their environmental improvement potential

Goals, measures and auditing

Goals

> *“Lean encourages the use of simple useful measures”*
>
> [Company A, respondent A, #1]

> *“we’re all here to perform a job and it has to be done safely, it has to be done to a certain quality, it has to be done within a timeframe. And so it doesn’t matter what you do, whether you’re* (carrying out manufacturing roles) *or preparing a balance sheet, and so often people tend to forget that whatever they do, there’s a full metric that applies to everything they do”*
>
> [Company C, respondent B, #5]

Researcher – "*So what would you say are the main impacts you have here?"*

Respondent B - *"The way we measure it, we've probably got about 15 main impacts that we measure and report, and there's 3 main ones – energy consumption, plastic recovery (regrind) from the waste stream, and reduction of powder from the powder coating process. There's a couple of others that we could use that are sort of bubbling away just under the surface, and the plan is that one of those drops below the threshold and we raise one of the others up and start working on that. The big ones in the background would be scrap metal segregation, paper and cardboard recycling, waste segregation program, and I'd say returnable packaging."*

Researcher – *"So how did you work out your main impacts?"*

Respondent B – *"They're on a scale of measurement so we have a set program where we take into account the legal requirements first and foremost, then mainly the size of it, the frequency, the quantity of the product that's held on site or being processed, or it could be customer driven…"*

[Company D, respondent B, 1h01]

Most of the companies interviewed (seven of the ten) stated in their response to question eight that they use regular measurement against goals or auditing, and work out the effects of Lean from changes in these standard regular measures.

Some companies (in particular company D) already had a very clear system of focussing their environmental improvement efforts by using goals. They had a number of categories of environmental impact and focussed on those they had calculated to be the most severe. These were not at the time of the interview integrated with the Lean program but their Lean nature meant it would be easy to incorporate them if necessary. Company E already had environmental targets amongst the Lean ones in their Lean implementation structure.

To fit into the Lean implementations, **the integrated tools should incorporate environmental goal setting** [I4-15].

Measures and auditing

> *"I'm very conscious of driving the wrong behaviour…. ….*(measures are for) *are you doing it right, are you driving improvement, if you're not changing behaviour… …stop measuring"*
>
> [Company B, respondent A, #15]

> *"we've installed telemetrics in our vans and it's had an effect already"*
>
> [Company E, respondent B, 2-18 min]

> *"We've done LCAs… my personal view is that that isn't a very useful thing to do… …I'm not sure what LCA information would drive you to do, how you would use that information to improve?"* (because there is a lack of different enough alternatives to be useful to compare, for this company)
>
> [Company G, respondent B, 2-20min]

> *"if you talk to the guys in the operation they'd say that* (workplace audit) *is the one tool that's sustained the change"*
>
> [Company E, respondent A, 22min]

The first three quotes are all stating that the point of measurement should be to influence behaviour, or that applying measures is effective in influencing behaviour. The fourth shows that auditing, which is the regular monitoring of measures, is key to sustaining change (probably because auditing demonstrates that managers think that what is being measured is important, as well as giving managers an indication of when improvement is not maintained.

When asked about synergies between Lean and environmental improvement, one of the respondents felt that Lean's approach of encouraging measures and targets would be helpful in making environmental improvements.

Bringing all this information together suggests that **measures should be selected to try to drive behaviours that will achieve the environmental goals** [I4-16], and **to ensure that environmental improvements towards the selected environmental goals are made and maintained, the selected environmental measures should be included in the workplace audit system if one exists** [I4-17].

Goal cascade

> *"Whatever role you're doing can you see how it fits in the wider picture?"*
>
> [Company E, respondent A, 1h09min]

> "(each workstation operator) *….knows they are operating a key characteristic and CPK has to be … and the SPC charts are …"*
>
> [Company B, respondent A, #2]

Companies B, D, E and I all set overall goals for the whole company, and then broke these overall goals down into a number of levels of sub-goals appropriate to each level and role within the company, in such a way that fulfilling the sub-goals would lead ultimately to fulfilling the overall goals. This is often referred to as a cascade of goals, although these companies did not all call it by this name. In company D a poster was displayed throughout the works (so that it was visible to everyone in the company at all times) showing all the goals set out in a pyramid, how this cascade worked, and the goals at different levels in the company. Company B had a less formalised version but still were careful to make sure that goals were appropriate to the level and role of the employee – in other words the goals they were set must be something achievable for them within their role. For these companies **it is important that all goals set should be achievable for the role and level they are set for, and build towards the overall company goals** [I4-18].

Standardisation, measurement and control

> *"We're actually using 0.3% less water per head than the national average for this size factory. It's worth thinking about that because as Lean goes, you'd say to yourself if we were using four times the national average per head for a factory this size, you'd know there were likely to be some significant savings. But we're 0.3 within it so how much time and effort are you going to use to get improvements? Very little. But without doing that calculation and looking at that you don't know. Any improvements you try to do are going to take a lot more money (for a small improvement). What you can say is well OK we're doing OK, put it on the back burner but it's a great project for new environmental champions that are coming up there, because they're looking at something that's already under control so when they start thinking about these things they're all there"*
>
> [Company D, Respondent B, 1h44]

"Part of the considerations for sustainability should be putting in some form of measurement – easy measurement, that can be tracked. Because that's the only way you know if you're sustaining it or not. Another thing that we do is we do regular audits and that also helps to show, but if you want to look at it on a daily basis you need to have some form of measurement in there that you can look at daily, that shows have we gone up, have we gone down, have we stayed flat, because if you don't have that, you don't know if you have improved, you don't know if you're sustaining it, and if you want to do another improvement you don't know where you're starting from."

[Company D, Respondent A, 1h46]

One of the tenets of Lean is that before attempting to improve a process, the process should be reviewed and current best practice standardised, and a measurement system put in place. In these quotations respondents are saying that because Lean has produced standardised processes, it is easier to make environmental improvements; that having measures and a history of those measures prior to making changes helps to show whether changes are effective; and that ongoing measures show whether the improvement is being maintained or improved upon.

In summary these quotes state that **environmental improvement is more effective when processes are under control, standardised and have appropriate measures and auditing systems in place** [I4-19].

Further, respondent B at company J, when asked about synergies between Lean and environmental improvement, suggested that environmental best practise could be standardised in the same way as other best practice [company J, respondent B, 1-1h18].

CI and workforce involvement

"I kind of hung the hat on Lean because when you're working with smaller companies you can't sell people involvement you've got to sell something you can grab hold of"

[Company B, respondent A, #8]

"I do know people who try to take short cuts. And I think it's one of those situations where you can't actually continue to support the work you have to do because you haven't addressed the cultural side of it"

[Company C, respondent B, #4]

“people do the tools, but there is the aspect of management systems, visual control, the people, the teamwork, continuous improvement that people… not forget about but that’s the difficult bit”

[Company B, respondent A, #1]

“My first 9 months here was just people-ing, team-ing and engagement-ing – digging the foundations”

[Company B, respondent A, #20]

“…just the management team went down it (pre-Lean demand flow technology training), *not the workers, none of the workers went down it – the management team came back and tried to do this to the workers and it didn’t quite work so it was one of those you get in some factories where we had “oh here’s another one, let’s see how it works”.”*

[Company D, respondent A, 2m]

“We have a team onsite – there’s four of us – and they’re all very enthusiastic and I think the problem we have is to engender that enthusiasm in the workforce – we have to keep doing that”

[Company F, respondent B, 10m]

The quotes above all outline how important people are in Lean, that Lean is more effective when the workforce have greater involvement in the process, and more specifically how **it is important in Lean to involve in the implementation the people in a company that work on the shopfloor (who are the most likely to be adding value directly, by the Lean definition)** [I4-20]. Responses to questions throughout the interviews reinforced this idea that it was important to respondents that Lean was something that was done by everyone, at all levels within the company. One of the reasons commonly given for disliking the involvement of consultants in implementation was that they only trained managers and did not run training for shopfloor workforce, and in the responses to question ten five of the ten companies stated that cultural changes and changes in people’s attitudes were the most noticeable changes in their operations once they started implementing Lean.

“It sounds trite but it really is genuinely done here. Operators, teams, team leaders are empowered to drive their own local CI”

[Company B, respondent A, #5]

“When the Lean team walked away the local team continued the improvement another 7%”

[Company B, respondent A, #13]

"Now we've been mentoring and training the people and they can start to understand and identify, and they've got the freedom to go ahead and do a project. Whereas before it was coming from the top down, now it's bottom up, and that's what we want, really."

[Company J, respondent B, 15m]

"A lot of it's accelerated itself, because people have got hold of it. It's not always management and the company that drives it, it's the people that drive it themselves"

[Company J, respondent B, 28m]

"If we didn't run a major project we would be status quo – that's the culture. It's almost like hand grenades – if I throw a hand grenade, I get a result, if I don't, I get what I get"

[Company F, respondent A, 3-25min]

"We always want to train people to do things, we don't want to have to run an event to do a set up reduction, it should just be what people do when they come to work"

[Company C, respondent B, #8]

"I'm constantly raising the bar. I need to have that energy and keep driving but you have to take people with you… …as an individual I think I drive this fairly hard"

[Company C, respondent A, #1]

Companies recognised that the ideal state was one where shopfloor participants are empowered to make improvements themselves, but the extent to which Lean is self-driven varied among the companies interviewed. Respondents from Company C and Company F are explaining that although they see the desirability of Lean being self-driven by the shopfloor workforce, at the moment the implementation and improvement process are driven by management. On the other hand, companies B, F and J's respondents state that in their implementations, participants are driving improvement themselves.

"Obviously along with that was the cultural change, getting people used to changing the way they do things. The amount of times I've had people saying "I've done it like that for 20 years you're never going to improve it" and we do. As people started getting used to it you started hearing "this really does work" "it's saved me time""

[Company D, respondent A, 41m]

"I said how long does it take to (carry out a particular process) – and he said a week …. And I asked him again and again and he said a week, and eventually he said well how long do you think it takes and I said 40 minutes!….

…he said the whole process from taking (raw material) in to sending (the product) out the door took about 16 to 18 weeks – and I said we should be able to do this in 4 weeks. And they were just shaking their heads and saying who is this guy, who's just come to us and talks a foreign language and talks about things that we've never heard of, and now he says we can make (a product) in four weeks! And they did a value chain map, and I wasn't involved in that, we kept me out of it and they came up with the idea that if they did this, never stopping, it would take just under 10 days. So as a result of that we now successfully offer a four week fast-track business service on certain orders for selected customers"

[Company C, respondent A, #3]

These respondents are explaining how they have observed that **the workforce gain faith in the process by being allowed to see it, try it and work it out for themselves** [I4-21].

"As part of Lean there's obviously lots of little things that have been done as a result of getting in people's minds taking waste out of processes – simple things like going into areas where there's one switch that controls lighting for say a whole office and he said, "well why can't we have it so there's a switch for that one, a switch for that one" – it's more controllable and we're using less power, less lighting and it's got that kind of thinking into people's heads. There's probably lots of little things that are being done there – lots of them. It's a shame you can't pull them all together and see the overall impact"

[Company I, respondent B, 1h36]

"So as a result of that (we now successfully offer a four week fast-track business service on certain orders for selected customers"

[Company C, respondent A, #3]

> *"I find there's about twenty or thirty percent where you think, yeah, he's really got it there… we can use less gas, less electricity so it saves us money and works for the environment"*
>
> [Company I, respondent B, 1h8]

The interviews showed that **the workforce can make a valuable contribution to workplace improvement, including environmental improvement – for example through suggestion schemes or involvement in improvement projects** [I4-22]. Companies D, J and K explained that their CI schemes produced suggestions on a wide spectrum of scales – from simple suggestions with small benefits to others which had the potential to make major savings. Company I in particular highlighted energy saving suggestions such as rationalising the compressed air delivery system, which was suggested in order to make financial savings, but would do so by reducing energy usage and therefore would also reduce environmental impact. This company actively encouraged employees to make environmental improvement suggestions within their suggestion scheme, which pre-dated the Lean implementation.

Company F expressed desirability of environmental improvement being part of everyone's normal job.

Training

Most of the companies mentioned training of the workforce – either they trained everyone throughout the site early on, or they trained people in an area prior to starting Lean improvements in that area. At companies C and J the respondents talked about using videos to train people to "learn to see" waste and distinguish between wasteful and value-adding activities; several companies discussed the use of games and guided activities (e.g. waste walks) to allow participants to learn by doing. It follows from the importance of training the workforce to identify wastes and learn how to use Lean to deal with them, and the synergy acknowledged above between environmental and Lean wastes, that **participants would need to learn to see environmental wastes at an early stage in an integrated implementation** [I4-23].

Mapping

> *"They're actually using Lean tools to map, track and identify areas of improvement in our waste streams"*
>
> [Company J respondent B, 1m]

“if this business operated fully to Lean principles what would it look like at a very practical level? …so those are the things we would see. And then, what’s the plan for the next 12 months to help us get nearer to that?”

[Company E, respondent A, 20min]

“We mapped the future state of what we wanted to achieve – we do a lot of visual mind mapping – and then break that down into a summary of actions to achieve the future state”

[Company F, respondent A, 3- 0min)

“You can’t just say let’s do a kaizen over there next week or next month or let’s do that in six months time. Although when I say that, I’m always reminded a bit of my4 year old son who was drawing a picture and I said, that’s good, what is it? And he said I don’t know, I haven’t finished it yet! You can’t just dabble and then see what it looks like, you’ve got to really know the picture is and have a plan for a future state.”

[Company C, respondent B, #6]

“Sometimes it comes down to an obscure area that you would think had nothing to do with the area you were originally working on”

[Company C, respondent B, #7]

These quotes show the two main ways of using mapping that were identified during this research. Firstly, a current state map can be built up and used as the basis for a future or ideal state map, and then comparison of the two can be used to plan the transformation steps needed to reach the ideal state.

Secondly, the current state map can be used on its own as the basis for discussion of where the worst problems are and where attention should be focussed next. In discussing this approach respondents suggested that using a map of processes in a value stream helped them to understand the effects of problems in one process on another, or to see the root cause of a problem in one area which is sometimes in a quite remote or unconnected process or area [Company C, respondent B, #7]. Current state mapping can show these interconnections.

Also when asked about synergies between Lean and environmental improvement, the respondent from company H suggested that environmental improvement could benefit from mapping exercises, perhaps by mapping energy usage throughout the value stream.

It seems likely that **the benefits gained by those companies using mapping in their Lean programs might also be useful in their environmental improvement efforts by helping them identify where to act, to define an improved future state and define steps to reach that state** [I4-24]. As they already have expended the effort to create the Lean maps, it should be possible to find ways to gain benefit for the environmental improvement with little extra effort.

4.4.6 Mechanisms for integration

> *"if you wanted to bring the environmental side in you could expand on the waste elements. We could quite easily do that in what we're doing today"*

[Company I, respondent A, 1h25]

> *"If we did do that* (add environmental measures or goals for Lean activities) *I could quite easily say to* (respondent B) *we did a cell workshop there and as a result of what we did, we've saved this on electricity, this on lighting, that on that… … we could do that on each activity we've got, but we don't* (add environmental wastes to the Lean wastes) *because we've said no, there's seven wastes. I've read that you can add all the environmental ones if you wish, and to be honest it's a good idea sitting here thinking about it now, to do that, because in terms of the people in the business it would be new opportunities for them, to start thinking about more improvement opportunities"*

[Company I, respondent A, 1h58m]

> *"as you get into the environmental stuff what is it that shifts it from words to specifically what are you going to do?... …what's the underlying intent?"*

[Company E, respondent A, 45 min]

> *"one of your questions is about linking Lean and environmental sustainability and I think there's a lot that can be done, and I think the two can potentially work closely together, but it is all around intent"*

[Company E, respondent A, 46m]

> *"I think there's plenty of help out there for companies to understand what their obligations are and plenty of companies*

that will give you some support with ideas but in terms of converting that to reality I think companies have to do that themselves"

[Company F, respondent A, 2- 2m]

"I dislike buzz words – I'm quite happy to use them as labels, but I don't want somebody thinking it's a fad so that's why I avoid them. But in terms of explaining it to some people, often not the people who will be doing it but the people that need to believe in it – a structure like that is useful to hang stuff on. That's what you do for that bit, you kanban it… tools are like a prescription I suppose, and it would be neat to have a structure and a logic like that, and prescriptive remedies"

[Company H, 2-49m]

"I think in terms of developing new tools – I don't think we'd need to develop new tools as such, but purely and simply by exposing people to those other waste elements and making them aware of them, we'd incorporate them in the tools we currently use, that would be the easiest answer."

[Company I, respondent A, 2h00]

One of the key benefits of Lean to company E's respondent A is that it can make the difference between talking about changing and actually making changes happen. In these quotes he is predicting that integration might allow environmental improvement to make use of this benefit. Company F's respondent is explaining that the practicality of achieving their environmental goals can be difficult for companies – they know (or can get help to find out) what they want to do, but not how to do it. A further respondent felt that Lean could provide environmental improvement efforts with structure and logic, which would be beneficial; yet another, that it was important that departments cooperated and that everyone knew and understood the Lean tools.

The quotations from respondents at companies I and H in particular suggest that **it could be possible to integrate environmental goals and wastes into Lean and use Lean's framework to help companies make environmental improvements** [I4-25].

4.5 Negative case

A method for minimising bias is to actively look for evidence that disagrees with emerging themes within research. The researcher has done this throughout the research. In this phase, the negative cases were sought out during the original pass through the data and once again after completing the main process, in the second pass the researcher specifically sought out negative comments. The following negative cases are identified for this phase.

The nature of semi-structured interviews is such that it would be exceedingly strange for all the participants to give the same response in the same way at the same point. Even if they did, this research is based on a small number of companies so it is not possible to say that “all companies think” anything. Most of the findings in this chapter are based on responses from some of the companies so there is a potential negative case in that the other companies did not mention the issue at all, or did not mention it in the same way, and so the findings are worded accordingly. An example of this is finding 3 [I4-3] which discusses the tools that might feature in an integrated implementation. This finding draws together the key features that occur most frequently in respondents’ discussions of their implementation, even where they might use different terminology for similar ideas, or not all companies use all the tools. The finding is worded accordingly – it gives the common, not the universal tools, and it also explains the purpose, which is guidance on tools that should definitely be considered for integration.

There are two instances where one respondent actively disagreed with the general consensus.

The first instance is finding 4 [I4-4] which says that in general companies have not integrated Lean and environmental improvement. Company J are deliberately trying to make environmental improvements within their Lean scheme so this statement is not universal, but it is still useful to know that the general state is a lack of integration, so the finding is given but worded appropriately.

The second instance is finding 5 [I4-5] which states that in general reactions to integration were positive. The discussion of this point explains that company C’s environmental respondent stated that he did not think environmental improvement via Lean was a good idea. Other respondents had found the idea of integration strange at first, so the finding is modified by saying that respondents felt integration was a good idea “in general” and “once it was proposed for discussion”.

4.6 Findings summary

In this section the findings from this chapter are grouped according to the research question whose answers they will inform. Further interim findings are proposed that do not as yet fit into a research question but will inform the later stages.

Research question 1 - If there are synergies and similarities between Lean and environmental improvement, what are they?

I4-6 Both Lean and environmental improvement are concerned with waste

I4-7 There are environmental impacts within the Lean wastes.

I4-11 There are environmental improvement side effects from a standard Lean implementation

Research question 2 - How can the synergies between Lean and environmental improvement be used to inform integrated implementation?

I4-8 Companies can save effort by considering possible environmental impacts while planning Lean changes

I4-9 Lean ideas should be considered while making environmental improvements

I4-10 It would be beneficial for environmental and Lean departments to work more closely together.

I4-15 The integrated tools should incorporate environmental goal setting.

I4-16 Measures should be selected to try to drive behaviours that will achieve the environmental goals

I4-17 To ensure that environmental improvements towards the selected environmental goals are made and maintained, the selected environmental measures should be included in the workplace audit system if one exists.

I4-18 It is important that all goals set should be achievable for the role and level they are set for, and build towards the overall company goals.

I4-22 The workforce can make a valuable contribution to workplace improvement, including environmental improvement – for example through suggestion schemes or involvement in improvement projects

I4-23 Participants would need to learn to see environmental wastes at an early stage in an integrated implementation.

I4-24 The benefits gained by those companies using mapping in their Lean programs might also be useful in their environmental improvement efforts by helping them identify where to act, to define an improved future state and define steps to reach that state

I4-25 It could be possible to integrate environmental goals into Lean and use Lean's framework to help companies make environmental improvements

Other interim findings

I4-1 The tool-set should be designed to be flexible

I4-2 The adapted tools should not be the sole focus when explaining integration of environmental improvement with Lean

I4-3 Goal setting, Continuous Improvement, Mapping and blitz events should be considered for adaptation for environmental improvement because they are common elements of Lean implementations.

I4-4 In general companies did not integrate the Lean and environmental departments

I4-5 Comments on the idea of integration of the concepts, once it was proposed for discussion, were generally positive

I4-12 Most companies found it hard to be certain of the environmental impact of their Lean implementation because they did not intend to make environmental improvements and thus did not measure it.

I4-13 The integrated tools should maintain the emphasis on cost saving because this is an important element of both Lean and environmental improvement for many companies

I4-14 it is not always necessary for there to be a financial or other imperative to adopt Lean; companies will adopt simply out of a desire to improve

I4-19 Environmental improvement is more effective when processes are under control, standardised and have appropriate measures and auditing systems in place

I4-20 It is important in Lean to involve in the implementation the people in a company that work on the shopfloor (who are the most likely to be adding value directly by the Lean definition)

I4-21 The workforce gain faith in the process by being allowed to see it, try it and work it out for themselves.

4.7 Conclusions

This chapter begins by explaining the design of the interview, and how that fits with the interview aims. The findings from the interviews are presented in section 4.4, grouped thematically. Key findings are highlighted in each sub-section and are then summarised in section 4.6.

The methods used to avoid bias are set out in section 4.2.2. In particular, the use of quotes and discussion of how the findings were drawn from the interview responses are used to allow the reader to assess the validity and reasonableness of the findings. Negative cases are discussed in section 4.5.

The interview stage showed that there is currently little integration of Lean and environmental improvement, but that after discussion there was a generally positive response to the idea of integrating environmental improvement with Lean implementations. Respondents identified a number of synergies between Lean and environmental improvement, and suggested ways that these might be used in an integrated implementation. The findings from this stage showed that workforce involvement, training, goal setting and audits, continuous improvement, waste, mapping and blitz events are likely to be features of an integrated implementation. The findings also showed the degree to which Lean and environmental improvements are interlinked, and the benefits that companies might gain from integration.

5 Tool design and case study method

Chapter Overview

This chapter provides a recap of the findings from previous research stages that inform the tool and case study design. The tools are then described and explained, and the design of the case study method and how it fits around the tools is explained. Finally, the chapter conclusion explains how the chapter aims, set out below, were met.

Chapter aims

The main aim of this chapter is to explain to the reader the research tools that were developed as a response to the data gathered in the preceding research stages, in order to gather data during the case studies in response to the research aims and questions.

After reading this chapter the reader should understand what tools were developed; how the tools are a response to data already gathered and what data informed each tool; and how the tools were built into a case study design or method. The reader will be reminded that the tools were developed as a means to an end rather than as an end themselves, and will be told what research aim each tool is intended to fulfil.

5.1 Aims of the tools and case studies

The aim for the tools was to provide opportunities for manufacturing companies using Lean to integrate environmental improvement in the Lean program, and to respond to the findings of the preceding research phases, for example suggestions for ways to integrate Lean and environmental improvement, or suggestions or queries that needed clarification.

The aim of the case studies was to observe the application of the tools in real-world situations, and to gather data that will contribute to the answers to the research questions.

5.1.1Rationale for the use of tools

During the interviews it was found that the company representatives felt that tools were less important in Lean than elements such as workforce involvement so tools should not be the sole focus when explaining integration of environmental improvement and Lean (I4-2). However the design of integrated tools was necessary in order to provide some structure to the implementation, to initiate the change of mindset and to act as a starting point for discussions with companies – and although the use of tools was not the most important aspect of Lean, respondents at all companies described some set of tools, activities or procedures that they would follow to initiate Lean thinking. A toolset was useful in this respect because it could be presented as a set of quite minor changes that could be discussed and tailored to the company's requirements (I4-1).

It has been mentioned before but is perhaps worth emphasising again, that in this research the tools were a means to an end rather than a research aim; they were simply a way to introduce the idea of integrated implementation as the intervention which was required in order to use action research methods.

5.2 Provisional tool design

Figure 5.1 shows how the selected tools fit into a basic change programme of setting goals, training participants, taking action, then maintaining and continuing improvement. It also shows the reason for each stage. The tools are defined in the following sections.

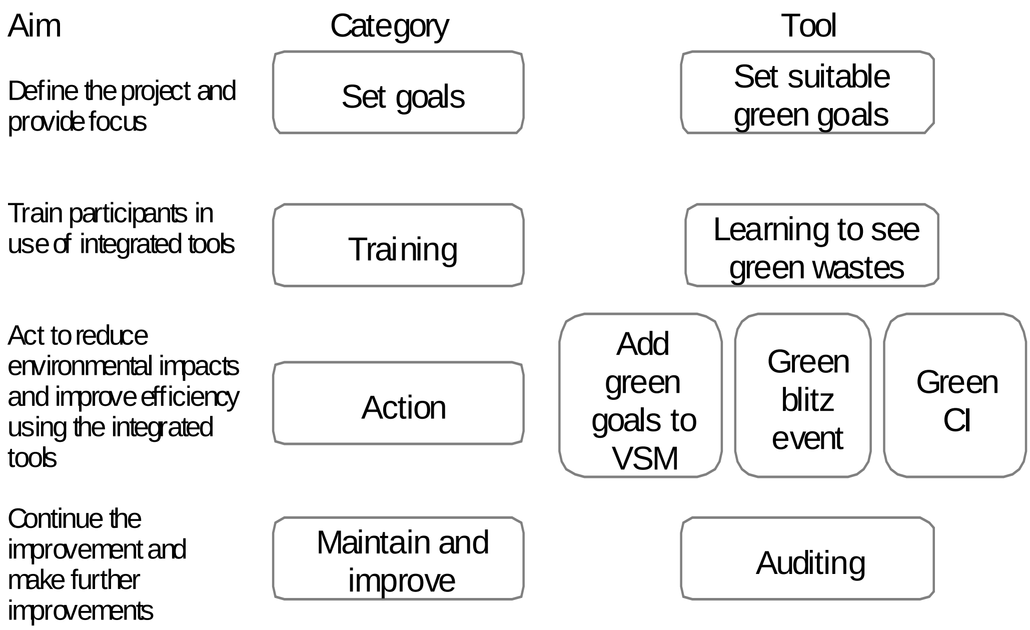
5.2.1 Environmental goals and measures

Description

As a first step to integrating environmental improvement with Lean, it was decided that companies should select three or four environmental impacts to target for reduction. Ideally these were to include at least some of their most environmentally damaging impacts, but cost, public relations etc. might also have a bearing.

The environmental goals were to be included in their list of Lean goals and be treated and applied in just the same way, if they have specified Lean goals. This was to include setting appropriate measures to operationalise the goals, and "cascading" the goals to all levels within the company if this is their normal approach.

Figure 5.1 – Diagram showing provisional tool outline



Reason

This tool relates to the following findings -

> I2-4 The Lean methodology can be used to make environmental improvements just as it would be to make productivity improvements
>
> I2-10 The need to set goals seems universal across Lean and environmental improvement literatures
>
> I4-3 Goal setting, Continuous Improvement, Mapping and blitz events should be considered for adaptation for environmental improvement because they are common elements of Lean implementations.
>
> I4-15 The integrated tools should incorporate environmental goal-setting.
>
> I4-16 Measures should be selected to try to drive behaviours that will achieve the environmental goals

I4-18 It is important that all goals set should be achievable for the role and level they are set for, and build towards the overall company goals.

I4-25 It could be possible to integrate environmental goals into Lean and use Lean's framework to help companies make environmental improvements

Research Aim

To find out –

- What method and criteria do the company use for selecting goals and why?
- How do they weight cost, operational and environmental impacts?

5.2.2 Addition of environmental goals to value stream map

Description

This tool was difficult to specify in advance because the interviews showed that the way in which companies carry out and use mapping exercises varied enormously. The intention was that the tool should fit in with the way in which the case study company used mapping in their normal Lean implementation, with the addition of measures relating to one or more of their environmental goals, in whatever way suited their mapping method and selected environmental goal(s) best. The resulting map would clarify the current state, and from this companies could then identify high impact areas and processes that should be targeted first by application of other tools, and/or identify a desired future state (with environmental as well as Lean specifications) and the steps that would be required to achieve it.

Reason

This tool relates to the following findings -

I2-9 The possibilities proposed for using mapping for environmental improvement could be arranged roughly into three groups; the use of mapping to ensure a thorough understanding of the current and proposed processes; the use of mapping to identify where the main areas of (environmental) waste are; and its use to promote a holistic view (by product families rather than departments) thus avoiding "silos".

I4-3 Goal setting, Continuous Improvement, Mapping and blitz events should be considered for adaptation for environmental improvement because they are common elements of Lean implementations.

I4-24 The benefits gained by those companies using mapping in their Lean programs might also be useful in their environmental improvement efforts by helping them identify where to act, to define an improved future state and define steps to reach that state

Research Aim

To find out -

- Would companies be willing to do this or see it as too much effort (Simons and Mason (2003) suggest the addition of calculated CO_2 emissions for all processes etc. which would be quite time consuming)?
- If they were willing to do it, how would they choose to do it and in how much depth? How would they use the results?

5.2.3 Environmental waste & "Learning to see"

Description

Environmental waste draws a link between *muda* (the term for wastes as described by Lean) and the environmental goals for Lean. Waste and its reduction are key to both environmental improvement and Lean but the definitions are different.

It was decided that learning to see environmental waste would follow the same pattern as is used in the company to educate participants about Lean and *muda*, which is typically a training session to explain *muda* plus a practical exercise to allow participants to try to identify it for themselves under guidance from trainers. This tool would add environmental wastes into both the training and practical exercise materials.

Reason

This tool relates to the following findings -

I2-8 The concepts of waste are so fundamental to both Lean and environmental improvement that the similarities and differences in the definitions deserve more exploration

I4-6 Both Lean and environmental improvement are concerned with waste

I4-23 Participants would need to learn to see environmental wastes at an early stage in an integrated implementation.

Aim

The research aims of this tool were to –

- Judge participants' reactions – do they understand what environmental waste is, do they think it is important to reduce it and are they willing to look for it, can they identify it and on what level?
- Assess whether Lean trainers are able and willing to support the environmental waste education

5.2.4 Environmental blitz

Description

Most of the interviewed companies used some kind of intensive action in a defined area as a mechanism to introduce Lean to that area, and make initial improvements, bringing all areas up to a certain standard to allow Lean working and continuous improvement. Again there would be scope for variation in the exact application of this action so this "tool" was simply a cue to include actions toward the environmental goals where possible in the blitz event, to be more closely defined to fit with the company-specific Lean "blitz" method.

This could be replaced by addition of environmental goals to whatever action the case study company customarily took in order to implement Lean, if they did not wish to use blitz events.

Reason

This tool relates to the following findings -

I2-6 Kaizen/Continuous Improvement (CI), kaizen blitz and workforce involvement are popularly suggested methods of gaining environmental benefit from a Lean implementation.

I4-3 Goal setting, Continuous Improvement, Mapping and blitz events should be considered for adaptation for environmental improvement because they are common elements of Lean implementations.

Aim

The research aims during environmental blitz events were to –

- observe the blitz event and note any discussions of environmental impact and attempts to reduce these impacts, or anything else relating to environmental impact reduction and the "environmental" additions to the program
- observe how the trainers integrated the environmental impact reduction element into the program

5.2.5 Environmental CI

Description

The environmental goals were to be integrated into whatever system the company used to generate and record CI suggestions. This was proposed as a way to continue taking action on the environmental goals, after the initial improvement gained from the blitz event.

Reason

> I2-6 Kaizen/Continuous Improvement (CI), kaizen blitz and workforce involvement are popularly suggested methods of gaining environmental benefit from a Lean implementation.
>
> I4-3 Goal setting, Continuous Improvement, Mapping and blitz events should be considered for adaptation for environmental improvement because they are common elements of Lean implementations.
>
> I4-22 The workforce can make a valuable contribution to workplace improvement, including environmental improvement – for example through suggestion schemes or involvement in improvement projects

Aim

The case studies were intended to take place over a relatively short timescale so it was probable that the researcher would see the setting up of this tool, but it was likely that the registering and processing of suggestions, and the actions resulting from them, would occur after the case study.

Therefore the research aim for this tool was to –

- observe the way in which the environmental goals are integrated into the CI system

5.2.6 Auditing

Description

If the case study company had any kind of regular checking or auditing system which aimed to ensure maintenance of improvement, encourage further improvement and demonstrate commitment to change and importance of goals, then the environmental goals should be incorporated into this system in some way. If audit results were displayed via the visual control system, then the environmental element should be incorporated into that as well.

Reason

This tool relates to the following findings -

> I4-17 To ensure that environmental improvements towards the selected environmental goals are made and maintained, the selected environmental measures should be included in the workplace audit system if one exists.

Aim

The research aim was to –

- Observe the discussion of ways to introduce auditing of the environmental goals and how, and if, this is introduced

5.2.7 Tools suggested in findings that were not used

The findings from the interview and literature review stages suggested many potential tools that could have been adopted. It was felt that to aid adoption the tool list should not appear too long or complicated, that too many environmental additions might make the implementation excessively complicated for organisers and that to try to introduce environmental elements in too many tools at once might have a detrimental effect on the research, not least by diluting the researcher’s time and focus.

In order to decide which tools should be adopted, the following criteria were selected –

- Those that indicated some intervention might produce or increase the environmental effect, rather than those where most of the environmental effect was from a “side-effect” of normal Lean

- Those that are accessible to companies just beginning the Lean journey and those at an early stage, as well as companies with more experience of Lean
- Those that earlier research stages indicated would have a strong or interesting effect, in the researcher's opinion
- Those that most of the interview companies used already (as the interview companies would be the first set to be approached for case study participation)
- Those that would be implemented during the time scale of the case study (likely case study duration would be approximately 6 months including preparation and planning)

The tools also had to fit together into a coherent program.

The following list of suggested tools and findings were therefore not adopted, although the flexible structure meant that if case study companies wished to use them, they could be brought in.

Kanban

The use of Kanban was indicated in the literature, summarised in this finding-

> I2-5 Lean and environmental impact reduction can work together – implementing kanban reduces inventory, thus reaping a raft of "Lean" benefits

Kanban was not adopted because the benefits identified in the literature were side-effects rather than active interventions.

Standard work

The use of standard work was indicated in the literature and interviews, summarised in these findings -

> I2-7 The ability to integrate environmental best practice into standard work could be a benefit of integrating environmental improvement with Lean

Standardisation of environmental best practice was not selected as it is something that companies are likely to do over a long period of time, so would not be done within the duration of the case study.

5S

The use of 5S was indicated in the literature, summarised in this finding -

> I2-11 5S schemes can result in environmental improvement through the introduction of segregated waste bins, reduction of storage space and reduction of wasteful activities liable to cause environmental wastes

5S was not initially selected although it became a key mechanism in case study 2 and in fact produced interesting results. At the tool selection stage, it was not selected because it was felt that the environmental effects were mostly side-effects. Note that company H, who hosted the second case study, and their advisor, chose to use 5S as the basis for their Lean implementation while incorporating the selected “environmental impact reduction and Lean” tools. The results can be found in chapter 7.

Just In Time

The use of Just In Time (JIT) was indicated in the literature, summarised in this finding -

> I2-12 Authors identify “unintended” environmental benefits from JIT, such as reducing wasteage of out-of-date components, treatments, etc., reducing vehicle emissions, and reusable packaging

The effects of JIT as identified in the literature are side-effects, and implementation of JIT would most likely take place in a different scenario from the tools that were selected. It is likely that much of the activity in implementing JIT would take place in negotiations with suppliers, whereas the other tools selected were relevant to training and initial implementation on the company’s shopfloor. For both these reasons, JIT was not selected.

Right First Time

The use of Right First Time (RFT) was indicated in the literature, summarised in this finding -

> I2-13 A serious reduction in failure rate could provide worthwhile environmental impact reductions alongside cost saving and other production benefits

RFT was not selected because the results identified were side-effects.

Statistical Process Control

The use of Statistical Process Control (SPC) was indicated in the literature, summarised in this finding -

> I2-14 SPC can be a very useful as a tool for compliance, in managing emissions (and/or quality), recording trends and raising the alarm when they are heading out of the acceptable range

SPC was not selected because it is not a core Lean tool and it is a tool that should be applied occasionally where appropriate rather than being applied regularly as a matter of course.

Six sigma

The use of six sigma was indicated in the literature, summarised in this finding -

> I2-15 Six sigma might be used as a way to define and solve the more specific environmental problems identified once a generalised environmental improvement program has improved the overall standards in a company

Six sigma was not chosen as it is not commonly used by interview companies. It is also not a Lean tool as Lean is normally defined, although six sigma and Lean can be complementary.

5.3 Case study design

Figure 5.2 shows that the case study design incorporates the tools outlined in section 5.1, along with the other elements that must be included to help companies apply the tools in practice and to allow the researcher to gather data relating to the application.

5.3.1 Additions to the tools in the case study design

Discussions

It was predicted that the discussions about whether to apply the tools, and exactly how to implement in this company if the implementation goes ahead, could yield valuable research data. In the later stages organisers would be asked to provide views on how well the implementation worked, but it would also be interesting to note their predictions on how the participants would respond, what might prove difficult or should work well, new synergies that they perceived, what was important to them about how to proceed and what aspects they were particularly enthusiastic about, understood easily, or those that seemed to encourage them to participate. The researcher would need to be alert for data of any form that would help to inform the research.

In practical terms it would be necessary to gain and maintain agreement to proceed and to work out with the company a suitable way to implement, and this would be done in the discussion sessions.

Pilots

Pilots are included in the design to allow the smaller-scale application of the tools in order to check that they would work and allow modifications to be made prior to the first main implementation.

Feedback

A feedback session was planned to ensure that there would be time for a final discussion where the researcher could get company perspectives on what worked, what did not work, and why this may have been. The researcher would also provide the company with some views on changes that might be beneficial should they choose to continue implementing in this way, and in turn would get feedback from the company on these ideas. Practically this would give added value to the company and for the researcher, it would provide more data, would form part of the bias avoidance procedure, and would provide an opportunity to discuss emerging ideas.

Query points

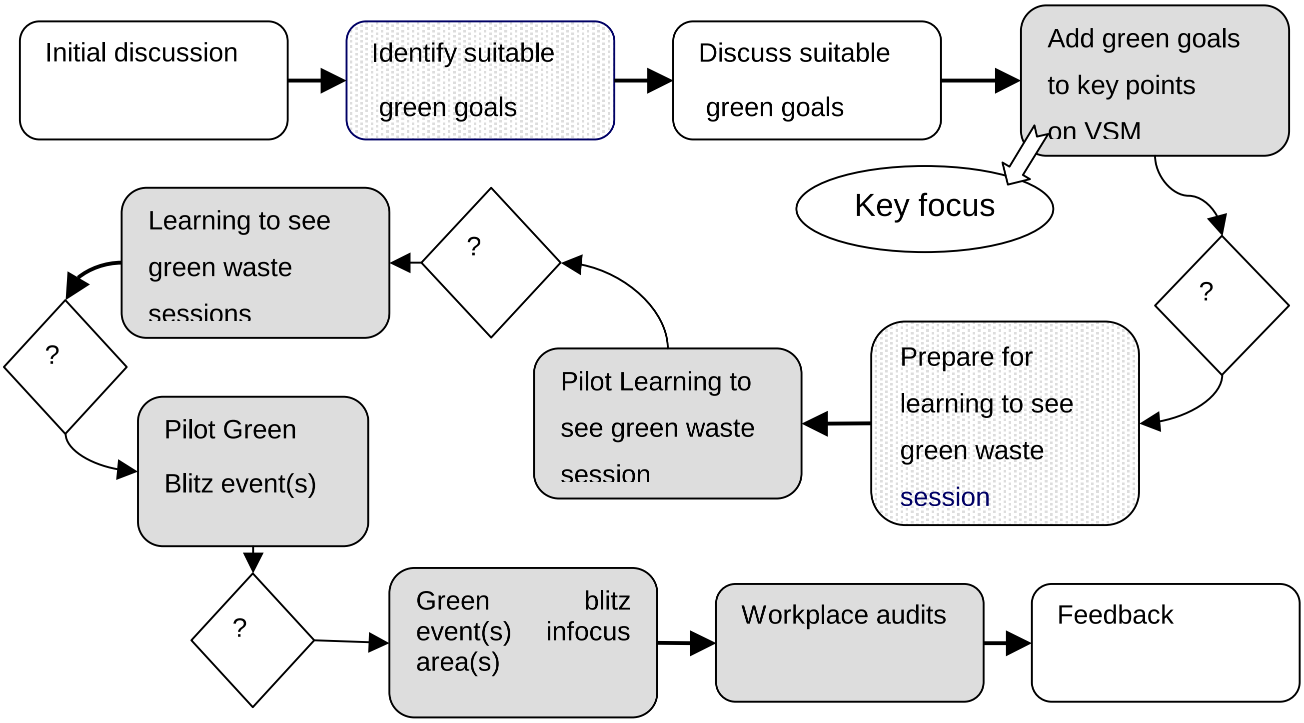
The query points were included in the design to give companies confidence when agreeing to implement as part of the research project that they would be able to exit the scheme at a number of points if they were not happy in any way with the direction the project was taking. Although this was a risk as it would set the research timetable back significantly should one of the companies choose to exit, it was felt that making it clear that it was a staged commitment might improve the chances of successfully recruiting case study companies, and that in reality they could have decided to cease involvement at any stage even if this was not made clear at the beginning.

5.3.2 Case study design features

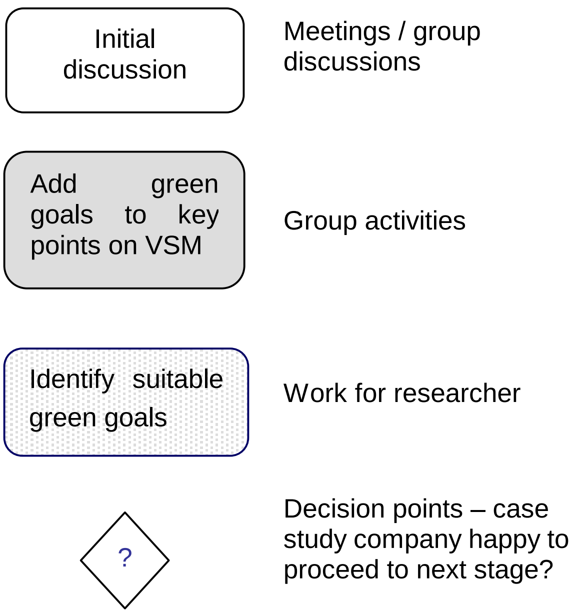
Role of the researcher

The role of the researcher in this action research structure would be both to observe the reactions of the organisers and participants to the implementation and gather other data, and to be an active particpant and provide assistance to the company in implementing.

Figure 5.2 – Diagram of suggested implementation structure outline



Key



The integrated Lean tools with environmental improvement additions were designed by the researcher, and the researcher was to take a leading role during planning meetings, helping the companies to adapt the generic toolset to meet their company-specific requirements; in particular, the researcher was to design company-specific training material to introduce the environmental additions to participants at companies, and was to present this training if required. The researcher would be present at key stages in the implementation when training and activities would be taking place, and would lead feedback sessions with participants and organising teams after the implementation.

Flexibility

The interviews indicated that flexibility in the design was necessary in order to fit with the range of different ways of implementing Lean. The case study was designed to achieve this by only defining tools at the top level, allowing for more precise definition through discussions with the company.

The choice of research focus supported this flexibility. The researcher took the decision that the focus of this research should be on identification and understanding of the way that Lean and environmental improvement can work together rather than on development of a toolset for its own sake. This meant that should the company choose to change the tool design this would be taken as data on the company's perceptions of synergies, thus eliminating a possible source of bias (as the researcher felt no pressure to ensure that the tools worked as initially designed).

Integration of ideas

It was decided that during the initial discussions the researcher would need to gather data from the company to allow the environmental elements to be integrated as seamlessly as possible into the Lean implementation. This could include templates for presentation slides and company-specific terminology – the researcher would also have to be alert for other ways in which this integration could be improved.

The researcher was to try to gauge, during implementation and feedback, whether participants perceived environmental improvement as an integrated part of Lean and whether that integration of concepts was helpful to them.

5.3.3 Data gathering

In general, it was decided that findings from the case studies would be noted as they appeared, and themes would be allowed to emerge from the findings as they were generated, just as they did in the earlier stages. However, the researcher would also need to check whether findings and emerging themes from the interviews and literature review were supported or negated by the case studies. It was decided that throughout the case studies, the following questions should be asked -

- Are there environmental improvements made as side effects of the Lean implementation?
- Compared to the literature and interview findings - are there more aims of Lean that show synergies, or more Lean tools that have potential use or that are used for environmental improvement, and do the case studies support the earlier findings, negate them, or neither?
- What factors for acceptance of integration can be observed?
- How important is cost reduction / are there financial imperatives for environmental improvement?
- How easily do participants and organisers understand the integrated elements?
- What inhibits integration? What differences or hostilities are there between Lean and environmental improvement?

5.4 Conclusion

The set of six tools designed are listed and explained in section 5.2. This section begins by showing that the basic outline of an implementation would be to set goals, train participants, take action, then maintain and continue improvement. Firstly it was envisaged that companies would set environmental goals in line with their top environmental priorities, and add these to their Lean goals. Training would be done by teaching participants to see “environmental waste” relating to these goals. There are three tools in the “take action” section which are environmental additions to each of; Value Stream Mapping, the blitz program and the Continuous Improvement system (this latter was also designed to help companies continue the improvement). Adding environmental goals to the auditing system was included as a way to encourage maintenance of improvement and further improvement.

As each of these tools was discussed in section 5.2 the findings from previous research stages upon which the tool builds were outlined. The tool descriptions also explained what research aims the researcher should keep in mind, while assisting with and observing the application of each tool.

Section 5.3 discussed the addition of discussions, pilots, feedback and query points to the tools, to complete the case study outline. Section 5.3 also explained how the case study was designed to provide research outcomes by studying the way that the tools were applied, and the avoidance of a potential source of bias by avoiding the need to prove that the tools work as envisaged.

6 Case study 1

Chapter Overview

This chapter of the thesis explains how the first case study was carried out and presents the findings from it.

The chapter begins by explaining the aims of the chapter and of the case study, then gives some background information about the company and the people whose input was most important during the case study. The chapter then goes on to outline the action research structure used in the case study.

The main part of the chapter explains each stage of the case study, based on the implementation plan which can be seen to be divided roughly into three sections; planning, implementation, and feedback and discussion of next steps. The section for each stage begins by explaining the aims for the stage, then the procedure that was followed, then discussion of quotations, the data and findings from that stage, as appropriate. The quotes presented in these sections were statements made by organisers, participants or trainers during the section being discussed, and were selected because they supported emerging themes or contradicted them, presented new and relevant ideas or information that might be the initiator of a theme, or were particularly strongly or emphatically expressed or given high importance by the speaker.

The chapter then goes on to deal with quotations that represent the "negative case" (those that go against the findings developing in the rest of the chapter) and considers what might be applicable outside the case study company.

Finally the findings generated in this chapter are summarised, with reference to the chapter aims.

Chapter aims

The chapter will explain how the case study proceeded, the data and findings gained from it, and how they can be interpreted. The chapter will show that the data summaries are accurate and that the findings are reasonable (i.e. that another researcher might reasonably have been expected to draw the same conclusions from the data), and will point out how bias was avoided. It will also present and explain any data that disagrees with the emerging patterns or contradicts other data or findings.

Notation used in this chapter

The notation used in this chapter is as follows:

- Interim findings are given as statements that answer one of the research questions. They are highlighted using bold text, and given a reference number afterwards in the form [I6-x], where x is the finding number, allocated according to order of appearance in the chapter's text.
- Quotation references or references to points made during a meeting that was recorded are formatted as [person, meeting, time]. For quotations, these references are situated on the next line and to the right. People are referred to by the abbreviations as allocated in section 6.2.2.

6.1 Aims of Case Study 1 – Company B

This case study aims to shed light on the research questions by intervening in a Lean implementation in a company and using action research methods to observe the effects of the intervention. In this case the intervention is in the form of explaining to the company managers the tools developed as a result of the data gathered during the literature review and interviews, as described in chapter 5, and then providing assistance for them to apply the tools that they choose.

6.2 Background

6.2.1 Company background

Company B is now part of a multi-national corporate group although it was established as a family-owned company. It has been in business for over 75 years, supplying plant to powered industrial equipment suppliers. Processes are predominantly automated or controlled by work stations with many poke-yoke features (for example at stations where air-powered screwdrivers are used, the product will not leave the station until the screwdriver has operated the requisite number of times to complete the operation; where there is a choice of components to fit, only the cover of the container for the correct component will be unlocked). Over one thousand people work on the shopfloor at Company B.

During the interview stage some information was gathered about the history of Lean implementation at company B.

At the time of the interview, nearly a year before the case study began, the company had been talking about Lean and six-sigma for three years. The OM had been in post for eighteen months, having worked with the company as a consultant before that, and some Lean implementation was begun but with most focus on cost-cutting events labelled as kaizen. The OM's preferred focus was on developing people and he worked on developing a Lean strategy that was more in line with that preference.

A Company-Specific Production System (referred to for the purposes of the thesis as a CSPS but named by the parent company to indicate it is their own version of Lean) was rolled out from the corporate headquarters and pilots began at company B. (Within the thesis, where points are made that refer specifically to this company's CSPS it is labelled as such, but where the points are made more generally that could apply to any Lean implementation, the term Lean is used).

Just prior to the case study the CSPS was finalised in a new form and the case study was carried out during company B's first implementation of the new format kaizen blitz event.

6.2.2 Participants

Company Organisers

Interaction with the company during the planning phases was with:

- Division CSPS deployment champion, CSPSC.
- Environment, Health and Safety department representative, EHSR. A member of the EHS department, with responsibility for training staff in the company's EHS policies and campaigns.
- Environment, Health and Safety Manager, EHSM. With responsibility for the EHS department and EHS policy and procedures for company B.
- Environment, Health and Safety Divisional Manager, EHSDM.
- Black Belt #1, BB1, Black Belt #2, BB2, Black Belt #3, BB3, and Black Belt #4, BB4. The black belts are the disseminators and trainers and main organisers of Lean within Company B.

- Company Specific Production System Trainer, CSPST. Visiting company B from the parent company's headquarters, responsible for overseeing training and the deployment of the new CSPS.
- Operations Manager, OM. His previous experience and time with the company are discussed above (section 6.2.1).

Participants

This term is used to refer to the members of staff who received training and participated in the Lean implementation (with "environmental" additions) which was the situation for the action research. The participants were drawn mostly from the shopfloor workforce (assembly and test operators, team leaders and team coaches) but also included personnel from the Engineering, Quality and Logistics/Stores departments.

6.3 Action research structure

The structure developed after the interim analysis stage using data up to and including the interviews was used as the basis for the first case study, and this is show in Diagram 6.1. Diagram 6.2 shows the modification made by company B (principally the CSPST). Diagram 6.3 shows how the events fitted into the planned stages, plus the main information flows between stages, to explain the actual sequence of events and how each stage was fulfilled.

As can be seen from these diagrams the intervention consisted of a series of meetings, training sessions and guided activities. Meetings were digitally voice-recorded and quotes were transcribed where they made points which related to the research aims of the meeting, added a new thought that was pertinent to the research aims, or corroborated (or disagreed with) a previous finding or thought. During the training sessions notes were taken of significant events, data, comments or reactions of the participants and trainers. Sections 6.4 onwards present this data, and the findings drawn from it, for each segment of the intervention.

6.3.1 Bias Avoidance

Section 3.7 (Methodology chapter) presented techniques for avoidance of bias that will be used at various stages in the research. This section explains which of these were felt to be appropriate to the case studies and how they were applied.

Involvement with the case study companies was as prolonged as possible given the time constraints of the research. In particular, plenty of time was spent with the companies in the planning stages of the implementation, where company representatives and the researcher worked together to ensure the implementation would fit both the company and the research objectives.

Peer debriefing was used in the case studies. A fellow researcher listened to a randomly chosen meeting recording and checked that the discussions and the findings drawn were reasonable (i.e. that he might have drawn similar conclusions, that they were an accurate representation of the points raised in the meeting). The methods, progress and findings and their context were discussed and checked with the research supervisor, at the planning stage and throughout the research. Throughout the research the researcher had a variety of sources of support and venues for discussion with fellow researchers.

Member checking was carried out during feedback sessions with the organisers, trainers and participants.

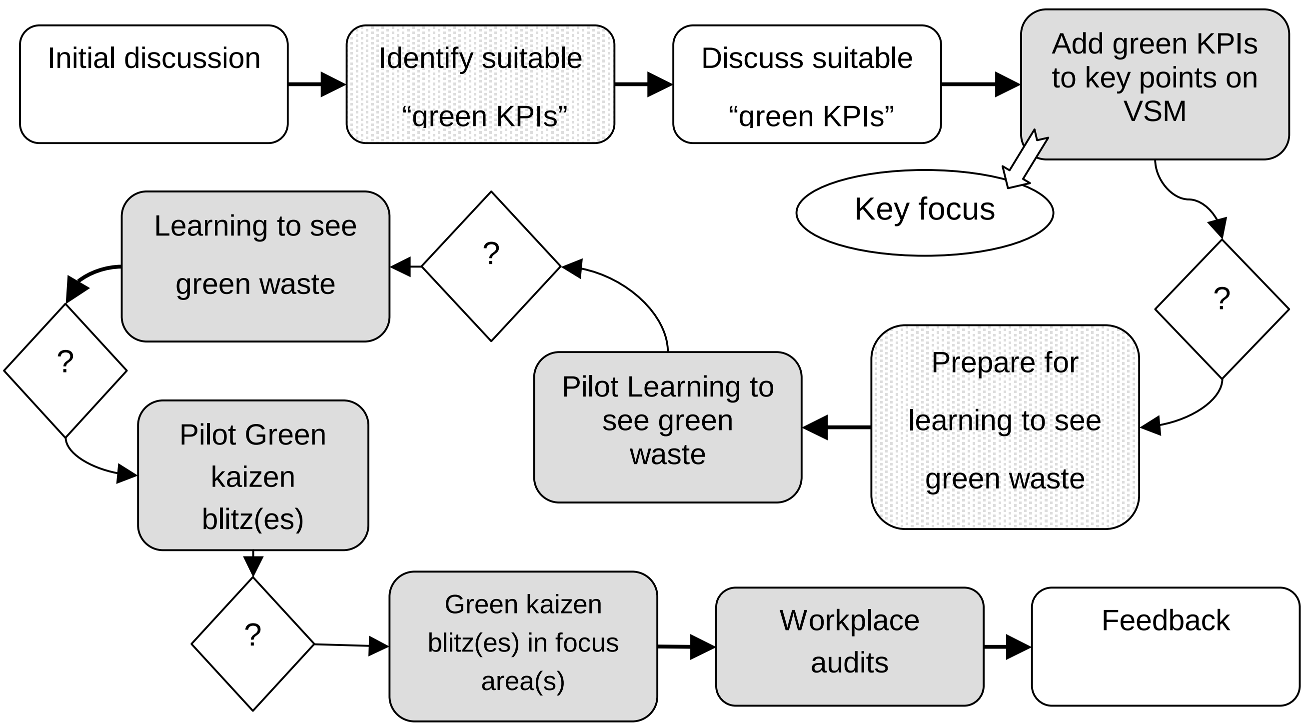
During analysis, the researcher looked actively for any data that disagreed with or modified the findings or emerging themes. This is presented in section 6.7 below.

An audit trail was maintained while doing the research by keeping notes and recordings on meetings, training sessions and other activities. Findings are discussed from the data upwards, with quotations and references to the comments made, to allow readers to decide for themselves that the findings are reasonable.

The researcher kept records of informants and could identify the source of all comments made. For protection of privacy of individuals and to maintain confidentiality for companies, these have been coded in any published material in such a way that the researcher can identify them but the sources are not identifiable by others.

The findings drawn relate to generic Lean implementations as they might be carried out by other companies, not company-specific processes or methods.

Figure 6.1 – Diagram of original, proposed structure of implementation



Key

Initial discussion	Meetings / group discussions
Add green KPIs to key points on	Group activities
Identify suitable "green KPIs"	Work for researcher
?	Decision points – case study company happy to proceed to next stage?

Figure 6.2 – Diagram of company B modified plan

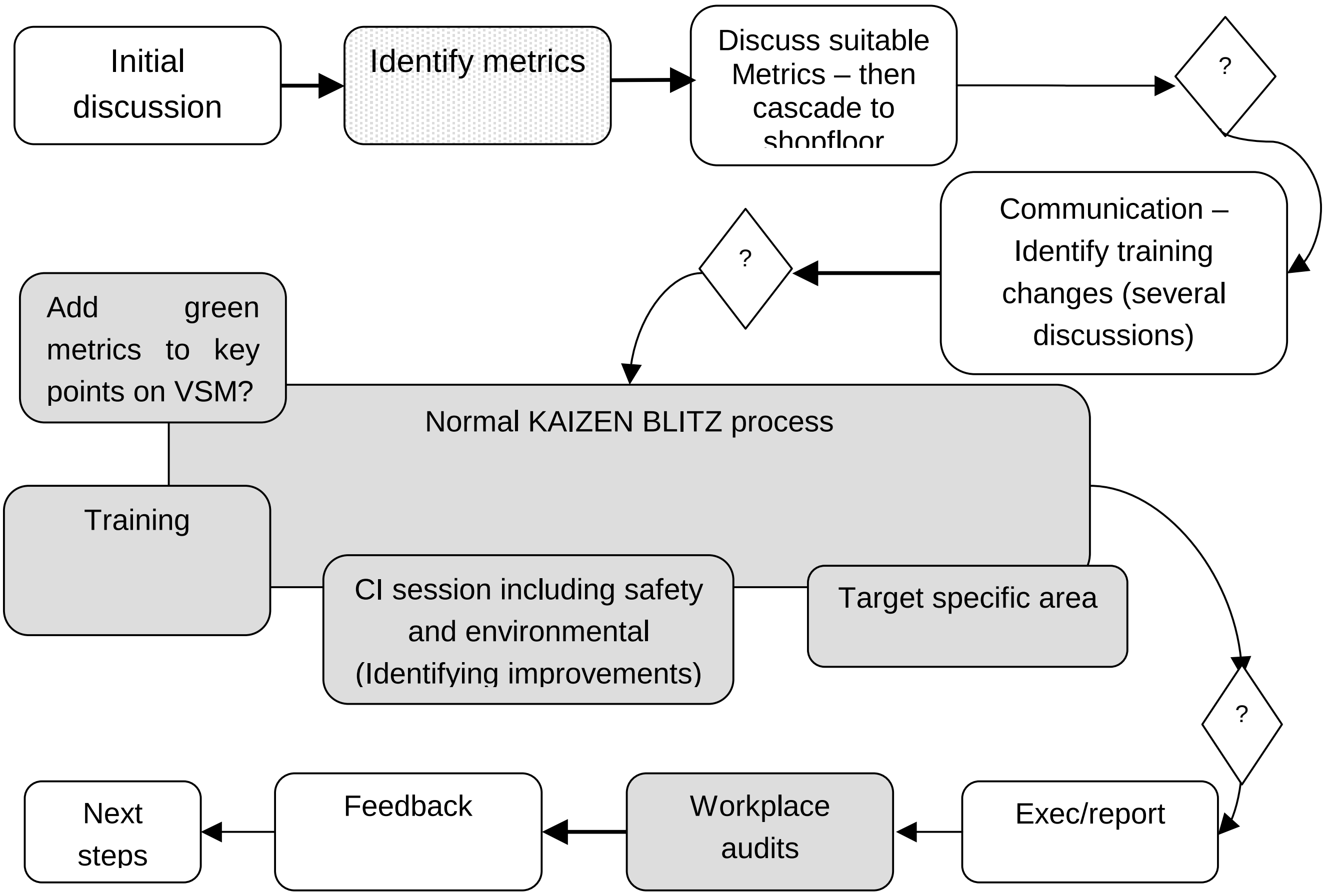
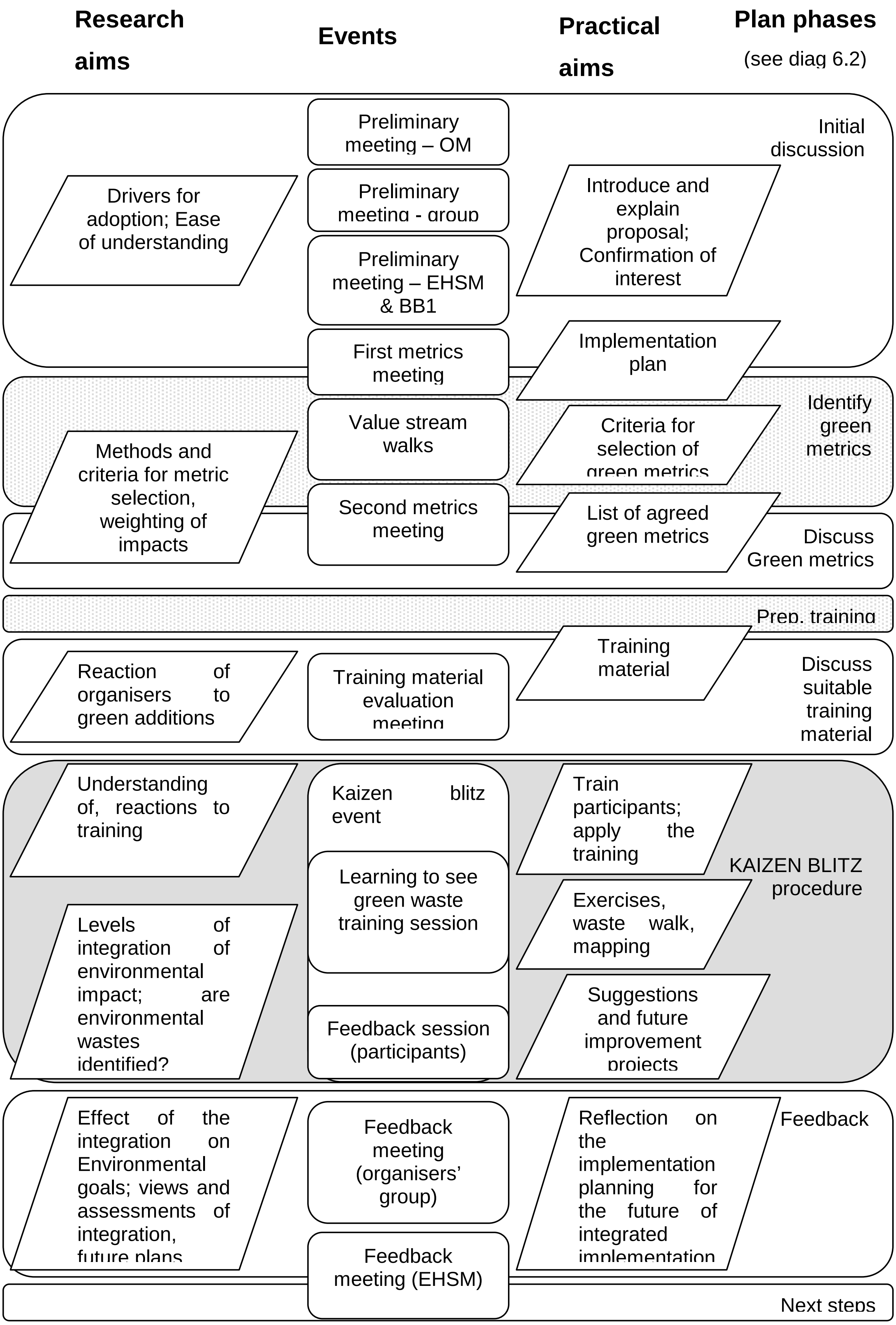


Figure 6.3 - Diagram comparing events with plan phases in case study 1



6.4 Familiarisation and planning stage

6.4.1 Initial discussions & familiarisation

Aims

The practical aims of these meetings were to introduce and explain the project and its principles and aims, and to explain the proposed form of the case study, in order to allow the company's representatives to decide whether they wished to take part; and to set up a succession of meetings.

The research aims were to discover –

- What made the company accept this proposal? What did they like or dislike about it?
- How well did they understand the ideas, and what helped or hindered their understanding?

Procedure

The first initial discussion meeting at Company B was with the OD, who was the first interviewee for this company during the explore phase and was able to give the ultimate approval for the project. The meeting was structured around a slide presentation which described the proposed intervention, but care was taken to explain that this would be used as a basic structure which could be modified during the planning stages to suit the company. The other important point to explain was exactly what the expectations from the company were and what the company could expect from the researcher, also mentioning that the proposed structure was staged, so the company was only being asked to commit to the first stage at this point.

The second meeting was intended to explain the proposed structure to the key personnel who would be involved in the planning stages of the implementation. In attendance were the EHS Manager (EHSM), the Company Specific Production System Trainer (CSPST) and Company Specific Production System Manager (CSPSM) (the EHSM was the second interviewee for this company during the explore phase). Unfortunately due to technical difficulties, these two meetings were not recorded.

Finally there was another communication and discussion meeting with the EHSM and Black Belt 1 (BB1), to familiarise BB1 with the proposed idea and implementation plan and discuss ideas and refinements.

Quotes and Observations

Responsibility and ownership

> *"…yes, you've got sustainability if they're doing things themselves… and the key thing we're trying to drive as we're doing these projects through* (the CSPS) *is capability building – and if we can build the capability of the guys to do environmental stuff as well, then it's a win for everyone I think"*

[BB1, second agreement meeting, 0m 5s]

> *"I think it's an opportunity in this organisation in that we don't really have ownership for energy… …So I think this is an opportunity to go over some old ground but then make people be aware that what they need to do is actually be responsible themselves – I think that's the challenge in this"*

[EHSM, second agreement meeting, 4m]

These two quotations are from a section of the second agreement meeting where the EHSM and BB1 discussed workforce involvement and ownership. The first quote explains that it is important at company B that the CSPS is something that is done by the workforce, not imposed upon them by consultants or managers or the CSPS team. The intention is that, once trained and having laid the foundations (VSM and future state map, communications boards in place, etc.) and gained some experience and confidence in making changes through the initial kaizen blitz event, the workforce take ownership of implementation in their area and are given time to do most of the work themselves. BB1 is also explaining here that he sees this as a parallel with environmental improvements, which he thinks could also be initiated by training the workforce to be able to make these changes themselves.

This is contrasted with a quote from the EHSM at an earlier point in the same meeting, who explains that the current state is a lack of understanding and ownership of environmental issues by the workforce.

In summary, **a key aim of Lean is to empower the workforce and encourage ownership of processes and their improvement, and both Lean and EHS staff perceive that this could also be beneficial in environmental improvement** [I6-1].

Acceptance

Agreement to the project was gained quite easily. The timing of this project proposal was fortuitous, as company B had recently been set environmental targets for reductions in carbon dioxide emissions and increase in recycling rates by their parent company, and this was probably a factor in the ease of acceptance.

The OM appeared to feel that **getting more benefit from activities they were already involved in was an attractive feature of integrating environmental improvement with Lean** [I6-2] (or the CSPS, for this company). The OM was recruited for his experience as a consultant using Lean techniques, to drive the Lean implementation, so this approach to problem solving is something he is comfortable with.

The OM was concerned that the project be presented to his managers by leading with the practicality and potential for cost savings rather than the environmental potential, as he seemed to think this would put off his managers. Interestingly though it was suggested in the second meeting that the company should emphasise that company B was taking part in this project for the "environmental" improvements rather than cost savings when presenting the training to the workforce.

BB1 commented on a further benefit of integration -

> *"We certainly don't want another initiative – if we can bolt it on the back of the CPS initiative then it's a bit of a win for everybody really isn't it?"*
>
> [BB1, second agreement meeting, 9m40]

He is expressing a feeling that there is a history of an excess of different projects running concurrently at company B, suggesting that the idea of maximising the effects of one project rather than running another one alongside it is attractive. BB1 felt that **integration has the benefit of reducing the number of different initiatives in the factory** [I6-3].

The main change to the initial proposed plan, suggested by the CSPST, was to cluster the events in the "implementation" phase within the "Normal kaizen blitz procedure", rather than having a sequence of events as in the initial proposal, highlighting the fact that they are integrated into this larger whole and will be fitted into the kaizen blitz event procedure as is most appropriate.

This also removed some pilot implementations prior to full-scale implementations, because this implementation was in effect a pilot study.

Understanding

Both the OM and the participants in the second meeting seemed to find that **the concept of integration and the proposed structure is quite easy to understand** [I6-4]. The OM and the EHSM had participated in the interview stage so were familiar with the basic concept of combining environmental and Lean improvement, but they had also understood quickly at that stage.

During the second meeting, the CSPST drew a modified version of the proposed plan, which he proposed should form the basis of this case study. This is worth noting because it showed that he had understood and engaged with the proposal enough to generate his own plan.

During the second meeting there was a discussion about how much flexibility there would be in changing the parent company's prescribed Lean procedures, which they were also just beginning to implement. It was felt that additions would be possible but key elements could not be changed – for example, it would not be possible to introduce an additional type of waste.

There were two pieces of terminology that the company wanted to change or found confusing. They wanted to change "green waste" to "industrial waste", because they felt that participants might confuse "green waste" with compostable waste which is often referred to as green waste. Secondly they wanted to refer to Metrics not KPIs as this fitted in with their in-house terminology. This shows that **terminology selected must be clear and unambiguous in the context of the company, and must fit in with their Lean and other in-house terminologies** [I6-5].

6.4.2 Select and discuss metrics

Aims

The practical aims for this section were to discuss ways to choose categories of environmental impact to target during the implementation, and once a provisional decision was made, to check agreement on these choices. The aim was to select categories that were among the company's largest environmental impacts, without spending a lot of time working out exactly which were the largest – beyond this the criteria for choice were open for discussion.

The research aims were to find out –

- What method and criteria do the company wish to use for selecting goals and why?
- How do they weight cost, operational and environmental impacts?

Procedure

The selection of metrics was discussed during the initial discussion and familiarisation meetings and findings from those meetings that relate to the metrics are reported in this section.

The researcher acquired the company's Environmental Impacts and Aspects Register, which had been prepared for ISO 14001 certification, along with an explanation of how the impacts were calculated, and these were used to provisionally select environmental goals for discussion. The method used to rank impacts is summarised in the findings for this section (section 6.4.2).

While this process was ongoing, there was a value stream walk conducted by BB1, for the researcher to gain an overview of the company's manufacturing methods and discuss what the shopfloor workforce had the opportunity to change. At this point the researcher had a provisional idea of the kind of metrics that might be selected so the value stream walk was an opportunity to check their suitability and discuss this with BB1.

Then there was a meeting with all those who would be involved in the organisation and authorisation of the implementation, in both CSPS and environmental functions, to discuss the proposed goals and to finalise the implementation plan. This meeting also included a value stream walk for this organising team, to discuss the ways in which operators might affect the proposed goals and for the organising team to try to identify environmental wastes with the company.

Quotes and Observations

Note that many of the quotations in this section make several different points and therefore appear more than once, in different sections.

Parent company environmental goals

> *"if we take the two metrics that are reported environmentally, one is energy, as CO2, and one is recycling as percent waste recycled, so those are the two units that are bandied around…"*

[EHSM, Initial discussion meeting 3, 16m 45]

This quote shows that there are two metrics that are likely to be suitable and are very relevant to the company – if these are chosen then the implementation can help company B to meet the targets from the parent company. It has already been stated that the timing of this project was fortuitous as this subsidiary company had recently been given environmental goals by its parent organisation, therefore it is not surprising that a key factor in choice of targets was to incorporate parent company goals.

Method and criteria for selecting top-level goals

To select the goals for this project, the researcher suggested that the company's Environmental Impacts and Aspects register (EIAR) be used. The EIAR is a list of all the environmental impacts that the plant does or might produce or cause, and for each impact there is further relevant information about its nature and likely severity, and actions taken or planned with respect to it.

Examination of the EIAR showed that some Impacts seemed more likely to be suitable for reduction within a Lean implementation than others. Because Lean is mostly to do with normal working routines, impacts that would only occur due to accidents (e.g. fires, floods or explosions) seemed less suitable; and those that related to other areas of the plant and were not influenced by actions from the area of focus could be disregarded. Similarly those impacts that required action by other functions than manufacturing (for example those that required product redesign) were also disregarded.

The company's risk factor assessment was then used to select from the remaining impact categories. The EIAR provided an assessment of the severity, frequency and likelihood, and the legislative or regulatory, cost and PR impacts for each environmental impact, on a scale of 0 to 10. Selection was provisionally made by taking the impacts with the highest sum of the first three scores (severity, frequency and likelihood) and these proved also to have high overall scores. The impacts selected by this method were waste materials (including waste paper, packaging that is not reused, scrap and other wastes that might go to landfill or be recycled) generated and the production of Carbon Dioxide (for example, usage of electricity, gas, or fossil fuels). These were presented with an explanation of the reasoning at the metrics meeting and the organisers agreed to them as top level goals, and to the logic for the selection. The "waste production" impact was divided into waste produced (which should be decreased) and percentage of waste diverted for recycling (which should be increased). With this addition, the proposed integration included action on the parent company's environmental goals.

Relevant goals for all roles and driving behaviour change

> *"So I'd suggest that those two* (top-level goals) *would be sensible - but how can we get them so that shopfloor employees understand those and their impact on those?"*
>
> [EHSM, Initial discussion meeting 3, 17m30]

> *"about adding green metrics to the value stream map – I think that's more about, as we've just mentioned, the consumption of individual bits of kit and I'm not too sure of the value of that. Because that's going down to the level of I'm using this machine to do this and that uses 2000kw or whatever it may be, but who's going to impact that?"*
>
> [BB1, metrics meeting, 19m 30]

In the first quotation, the EHSM mentions his concerns about current levels of understanding of environmental impacts on the shopfloor, and his view that an improvement in this area is needed – also he is implying that this project might act in this area. He is recognising the importance of cascading and is correctly foreseeing the difficulty of cascading environmental goals at company B. This point was much discussed but never fully resolved, except to say that participants would be presented with the top level goals and this implementation would be used as a trial to see how these goals might be "cascaded" effectively in future implementations. It was found that **setting suitable measures and targets for operators at all levels in the company proved much more difficult than deciding on top-level goals** [I6-5]

Another element of the issue of ensuring each role has a relevant goal is that the goals must be things that people working in that role can be expected to achieve within the scope of the role, which is what both these organisers mean by the impact of participants on the goal. It was important at company H that **goals selected for any given role must be those that someone working in that role could reasonably be expected to achieve** [I6-6].

Finally, it was also vital at this company that the **measures must be selected to drive desired behaviour changes** [I6-7].

Bottom up goals

> *"….OK so we can't measure the number of kilowatts of electricity a particular value stream uses, but what can we measure that would actually indicate we're using the right amount?… …it's about cycle times, it's about standard op.s, it's about doing the right thing, in situ, once, and so on and so on…. And actually that gives an indicative reading"*
>
> [OM, in response to EHSDM, metrics meeting, 15m 05]

> *"It's like, we need a more profitable business… you don't measure profit of section x and section y, you measure what they're doing etc.… and I think we're in that situation with energy - I don't really want to get embroiled in measuring the energy usage of each piece of kit that we've got in the manufacturing unit because there's probably 952 bits of kit and how much is that going to cost to put that into place?"*
>
> [OM (BB1 followed on, see below), metrics meeting, 17m45]

> *"I think what we need to do is not start from the top and work down, I think we need to start from the bottom. How much waste do they generate, how much energy… how much lights do they leave on when they shouldn't, how much equipment is running when it maybe doesn't need to, how much compressed air leakage have we got, you know, stuff like that – it's almost stuff like that."*
>
> [OM, metrics meeting, 28m 35]

> *"you could come up with or brainstorm a list of things we need to look out for when we're doing a* (Kaizen blitz event) *that somehow relate to the ninth waste for want of a better expression – is the tool being set up right, are the machines being maintained, is the oil level right"*
>
> [OM, metrics meeting, 29m35]

> *"as well as doing safety observations we could do green observations"*
>
> [CSPST, metrics meeting, 29m 50]

> *"…I think we need to have this conversation so that we can have in our minds what we might be looking for – and I actually think*

we've got to start from the bottom and work it up not start from the top and work down"

[OM, metrics meeting, 30m35]

The OM is suggesting here that **shopfloor goals need to be related directly to shopfloor actions rather than more abstract top-level goals**[I6-8]. Implementing this practically proved difficult, maybe because completion of the task was not assigned to a specific person or people.

This last comment from the OM was followed by an illustration using the resources that might be available to an individual who wished to become carbon neutral. He said that this would be enabled by a tool that said he had to measure for example how many miles he drove in his car, which was something he could then try to minimise, and that the targets for the operators needed to be similar –

"could we not draw up a list saying should I do this, should I do that, should I do this, should I not do that..."

[OM, metrics meeting, 31m 40]

It is unfortunate that this idea was not implemented and so could not be tested but it does seem that companies might beneficially provide employees with a list of actions and environmental consequences, or a checklist of simple work-related environmental actions.

Granularity, ease and cost of measuring

"The only thing for me that's missing from there is that when you're looking at green metrics they're sometimes not all that visible. So for example energy usage is one that (the EHSM) and I are struggling with at the moment and how to actually measure that at a local level. So with some kind of improvement in terms of energy efficiency, we can't at the moment at the local level effectively measure that, so we need to build that into that process somewhere, the measurement of these various kinds of impact – and I know that's not the intention overall of (the CSPS) but you've got to be able to tangibly see the impact"

[EHSDM, metrics meeting, 14m 30]

"It's like, we need a more profitable business… you don't measure profit of section x and section y, you measure what they're doing etc.… and I think we're in that situation with energy

- I don't really want to get embroiled in measuring the energy usage of each piece of kit that we've got in the manufacturing unit because there's probably 952 bits of kit and how much is that going to cost to put that into place?"

[OM (BB1 followed on, see below), metrics discussion mtg, 17m45]

"In this process we need to have a step that says.... .... can we measure it and is it easy to measure – and is it adding value to measure?"

[EHSDM, metrics meeting, 17m]

One problem identified here is the complexity and cost of measuring electricity use, for example, at a local level (say for one process or a group of processes) so that operators who make efforts towards the goal can see the effects of their efforts on the measure and receive due recognition. The company had been intending to purchase monitoring equipment but this did not happen prior to the end of the case study. This again was not resolved during the case study but the company came up with a way to resolve for future implementations (see section 6.6.3 - Future implementation of "environmental impact reduction and Lean", below). The possibility of taking measurements at the required granularity affected the selection of measures, not top-level goals.

In summary, **measures selected should be achievable at the local level at a cost that is deemed reasonable, so that participants' progress towards the goals is visible and can receive recognition** [I6-9].

Environmental waste

"…in terms of Lean, that affects how much efficiency we've got, and how much waste we've got, and how much energy we're using and are we using that energy in the most appropriate way?"

[EHSM, Initial discussion meeting 3, 17m]

The EHSM is presenting an assessment of how these environmental impacts have an impact from a Lean/waste perspective. The comments on efficiency and most appropriate use of energy are similar to the Lean definition of waste as effort that does not add value, which could be used as the basis for a definition of environmental waste in a Lean context. During this case study a definition of environmental waste was implied (by the setting of the goals) but was never discussed directly or made explicit.

> *"about adding green metrics to the value stream map – I think that's more about, as we've just mentioned, the consumption of individual bits of kit and I'm not too sure of the value of that. Because that's going down to the level of I'm using this machine to do this and that uses 2000kw or whatever it may be, but who's going to impact that?"*
>
> [BB1, metrics meeting, 19m 30]

> *"…I don't really want to get embroiled in measuring the energy usage of each piece of kit that we've got in the manufacturing unit because there's probably 952 bits of kit and how much is that going to cost to put that into place?"*
>
> [OM, metrics meeting, 17m45]

These quotations suggest a perception by some of the organisers at company B that energy usage can only be reduced by reducing the energy used by (value-adding) processing stages, whereas Lean would normally suggest a focus on reducing waste by identifying activities that are not adding value (in the case of energy usage this might be the movement of components within the site). This might be because of the choice of goals – most manufacturers probably believe that the majority of the electricity used on-site is used by the production equipment that is directly adding value, making it hard to ignore when trying to think about metrics that could drive energy-reduction – even though the approach the EHSM is suggesting in the first quotation is much closer to the way Lean considers waste. **A definition of environmental waste might be helpful to an implemented integration** [I6-10] and **the definition of environmental waste might begin with the concept of the appropriate use of resources** [I6-11]

Measures must add value and driving behaviour change

> *"about adding green metrics to the value stream map – I think that's more about, as we've just mentioned, the consumption of individual bits of kit and I'm not too sure of the value of that. Because that's going down to the level of I'm using this machine to do this and that uses 2000kw or whatever it may be, but who's going to impact that?"*
>
> [BB1, metrics meeting, 19m 30]

> *"In this process (of setting environmental goals and measures within Lean) we need to have a step that says.... ....can we measure it and is it easy to measure – and is it adding value to measure?"*
>
> [EHSDM, metrics meeting, 17m]

The first comment suggests that BB1 is questioning in Lean terms what measurements are actually going to add value to the business. The OM at company B is insistent that the reason for measurement is to drive behaviour change and this is something BB1 agrees with ([BB1, metrics meeting, 17m 40] & [BB1, metrics meeting, 18m15]).

The second quote is a summary of the concerns on measurement by the EHSDM. He and BB1 both expressed concerns about the value of taking measurements several times during the meeting (for example, with respect to the granularity of the readings [EHSDM, metrics meeting, 20m25]), and the point is well made that this should be a consideration when setting measures.

The "value added" language the EHSDM and BB1 use is interesting in that it draws another comparison to Lean, although it should also be noted that at no point was the value to the customer of the environmental additions discussed (nor was there any discussion of what specifically constituted value to company B's customers). In context, both seemed to be assessing the value of measures by their judgement of the likely ability of measures to drive the desired behaviour.

In summary, **value of environmental improvement to the customer is not yet defined** [I6-12]; and, **measures should be selected with the aim of driving behaviour that achieves the overall goals** [I6-13]

Application of value stream thinking and standard work to understanding and reducing environmental impacts

Following an explanation from the EHSM about methods for diagramming the environmental impacts of a process and the need for Company B staff to understand the inputs and outputs (in terms of materials, energy, etc.) and environmental impacts and wastes associated with a process–

> EHSM - *"but what you typically would do* (BB1)*, is you would typically take a square there and you'd say materials in, materials out, and the efficiency of it, because no true process is 100% efficient, so therefore you will lose some product, you will*

> *lose something because it's made into something else, so therefore my view in this state of utopia would be the person on the track says "yes, I understand that piece of process – it takes in metal and it comes out metal but I lose some metal but I also use energy and I have some noise and I understand the true environmental impact of that". So you're not saying, for every ton I have twenty tons of waste you're saying I understand that that's a value transformation in itself for every bit of kit and I know the value coming in and the value coming out but I also know the wastes involved with building that product. And I think that's where I would like to be - now that is utopia but then for me that means that we've got the awareness bit. Because do we really understand that we're digging something out of the ground and using* (xxx amount of) *electricity to make* (main component part) *and then it comes to us and we assemble it"*
>
> BB1 - *"I think that what you've just described there, we could do something close to that because in the not too distant future we've got to develop standard work for every op. station – we've got the standard op.s now but they don't comply with the corporate thing – maybe in the standard work we could build into that…. You've got your input, your output, which exists already but these are your outputs, the waste outputs – so maybe we could get to that."*

[EHSM & BB1, second agreement meeting, 39m15]

The EHSM's "utopian" ideal (that operators should understand the environmental impacts around their operation and its value stream) seems to have potential and is another link between Lean (in particular with value stream mapping) and environmental improvement. **Value stream thinking might be used to help operators understand the environmental impacts of their operation and its value stream** [I6-14]. BB1's response indicates that it would be a practical thing to do, and gives another example of the environmental possibilities of standard work, because **operations cards used by operators to follow standard work procedures could also include environmental inputs and outputs of the process** [I6-15].

Departmental integration

There is little formal interaction between the CSPS team and the EHS department, but once they began to work together most of the CSPS team and the EHSM were able and willing to start generating ideas for how to integrate the two concepts and make improvements. Observing the conversation between BB1 and the EHSM on the waste walk was interesting as they began to generate cross-functional ideas by having a conversation about their observations. Before the project, the environmental and Lean departments had worked together but only occasionally.

The first (paired) quotations [EHSM & BB1, second agreement meeting, 39m15] in the "Application of value stream thinking and standard work to understanding and reducing environmental impacts" section above also show that **there is potential for better integration of Lean and Environmental departments or functions to generate better solutions to problems through the application of different sets of knowledge, responsibility and ways of thinking** [I6-16]. It can be seen in this quote that the EHSM is contributing an outline of a suggestion for better understanding, and BB1 is responding with knowledge that the EHSM does not have, about a way to put the "utopian" idea into practice, that fits with work the Lean department are about to do and with the things that operators are likely to work with.

Do "environmental" goals contradict "Lean" goals?

> *"By measuring time and that you'll get better green metrics by doing it quicker, but you're also contributing to over-production"*
>
> [BB2, metrics meeting, 17m35]

This anxiety was not mentioned at any other point. It was dropped into the conversation about the value of measuring things and what should be measured to drive behaviour but was not dwelt upon.

6.4.3 Training material preparation and discussion

Aims

The aim of the "environmental" additions to the training material was to explain the concept of "industrial waste" and what the environmental goals are, why they are important and what people are expected to do about it. The additions needed to be a good match with the rest of the training.

The training material prepared can be seen in Appendix C.

The main practical aim of the meeting to discuss these additions to the training material was to check that the organising and approval stakeholders had a chance to review the additions and discuss any changes they wished to suggest.

The research aims for the discussion meeting were to –

- Find out what the stakeholders present liked and what they wanted to change, about the modifications to the training material.
- Continue to note the evolving attitudes to the concept.

Procedure

The researcher obtained examples of the other VST training material from the company, then developed an additional session on environmental waste using the same patterns, methods and styles. The session began with a reminder of the concept of waste in Lean terms, then moved on to define "industrial waste" (the company's chosen term for waste associated with environmental impact) and how it fitted into the concept of Lean waste, then discussing each of the targetted impacts – why they are important environmentally and what participants might do about them. This was then presented at a meeting to which the organising and approval stakeholders were invited, with a discussion session afterwards that was run slide by slide to allow discussion of possible ammendments to the proposed slides.

Present at the meeting were CSPST, CSPSC, BBs 1,2 & 3, EHSR (as the EHSM was unable to attend), researcher and researcher's supervisor. The OM was invited but was unable to attend.

Quotes and Observations

Environmental impact as an aspect of the eight wastes

> *"we need to be really specific about waste is a lot of different stuff, it's waiting, it's over-producing, it's over-processing, inventory, transportation, this is an example of waste in the value stream, you can find environmental waste anywhere in this yellow space, that's what we've got to try and get in there, because if I look at that and I'm telling the other folks about that, I'm thinking OK that's all the environmental waste I've got in there…. …it's like environmental waste is all mixed in with the*

other wastes in your value stream – that's how that can really come into play with that."

[CSPST, training review meeting, 17m 40]

CSPSC: "As we were talking through the linkage with our eight wastes before, had you looked at the particular green or environmental wastes that link with our ordinary eight wastes? and the reason I say that is because as you were giving examples there, overprocessing for instance, if we're machining more parts than we need to then we've got the CO2 stuff. Uuummm…. Transportation you've got your diesel, you've got your trucks and stuff like that."

CSPST : " …. think about the wastes and what would cause that waste. For example if I'm waiting on something, that would waste electricity and waste gas. That could tie back down later into this one. "

[CSPSC, CSPST, training review meeting, 19m30]

These quotes show that the organisers feel that wasteful activities can often fall into several waste catagories, including environmental wastes, and that **there are environmental impacts associated with the other eight wastes** [I6-17] – environmental waste was presented in this way in company B's training.

These quotations are suggesting in addition that **the environmental impacts to target using Lean methods should be those that occur in non-value-adding activities** [I6-18]

Language and terminology

CSPST : "This one here – I don't know if I want to say that (global warming) *– I agree with the premise, but from a political perspective… …from a political perspective I don't think we want to get into the global warming debate – but I think…"*

EHSR : "Change that to climate change"

CSPST : "Adverse impact on climate I'm OK with, but to say global warming would really I think send a message that I think we don't want to send as a business just yet."

[CSPST, EHSR, training review meeting, 20m45]

EHSR : "I don't want to sound a bit of a party pooper here – but what concerns me is "green" waste"

CSPST : "That's why I wanted to call it industrial waste…"

EHSR : "If I went out there and said to people "what is green waste?", it's garden waste that gets recycled through a mulcher and made into compost"

[EHSR, CSPST, training review meeting, 36m 30]

"…and that's particularly important if we want to integrate it into (CSPS) *and it's particularly important if we want to integrate it back across the enterprise later on. Our intention would be to integrate this into our* (kaizen blitz events) *for some time, for a few months, and then later on in the year, maybe Q3 or Q4, share it back with the enterprise*

[CSPSC, training review meeting, 48m]

The organising team were keen to maintain the terminology set by their main environmental training and information, to avoid confusion for the workforce and because it is quite important to the corporation that all companies maintain the "house style". Maintaining the same terminology and fitting in with the corporate stance on environmental issues would also make it more likely that the environmental additions to the CSPS would be considered for adoption throughout the corporation, if it worked well at company B. **Terminology used must be consistent and reflect the corporate requirements** [I6-19]

Education and "learning to see"

"… a lot of people interestingly will have the three bins at home, the brown bin, the black bin and the green bin at home, and will do recycling at home, and yet they come here and switch mode, they go into industrial mode a lot of them and lose that set of eyes and accept things as the norm because they've worked here for 28 years and that's always the way we've done it and it's trying to make that connection and almost shake the foundations a little bit and make them think "ooh blimey, I can't believe we've been doing that for all those years" and make them

uncomfortable about the whole thing, "what have we been doing? Blimey, I hadn't thought of it like that""

[EHSDM, training review meeting, 39m40]

CSPSC - *"If we look at – for this site for instance what were our absolute CO_2 emission levels for last year and then put that in the context that's equivalent to…"*

Supervisor - *"10,000 household's emissions or something"*

CSPSC - *"Yeah, something like that – that would make people go, "Oooooh",,,,"*

[CSPSC, supervisor, training review meeting, 41m30]

"I like the "did you know?" facts, that just switch people on to stuff. Because you know, it is about educating people isn't it? It's about giving them a bit of a surprise. And then, once you've sort of got their attention, and made them aware, there's some massive impacts."

[CSPSC, training review meeting, 51m26]

Here the CSPSC and EHSDM are referring to the conceptual link they have both identified between the need to teach people to see the waste of environmental impact in practices they had previously accepted as "normal" and the "*muda* spectacles" idea of learning to see waste in a Lean training program. As well as learning to identify these wasteful activities, they are identifying a need to understand the proportion of environmental impacts created by industry in general, and more importantly by this company, and how individual actions contribute to the company's impact, and what participants can do to reduce it. They are also expressing approval of this part of the method chosen to achieve this change of viewpoint. The three main points that they make could be summarised by saying that **participants need to learn to see environmental waste as well as Lean waste** [I6-20]; that **participants need to understand the importance of industrial environmental impact and how their actions are important in reducing it** [I6-21]; and that **examples are memorable and can make the training more personal** [I6-22]

Acting on environmental improvement suggestions

> *"There's actually two things, one of them is the continuous improvement process which is where we get ideas and then the suggestions are added onto a 5s checklist which becomes part of their daily routine."*
>
> [CSPST, training review meeting, 54m30]

The concept of the checklist seems sensible (it was also mentioned by the CSPST earlier in this meeting - [CSPST, training review meeting, 17m 20]) but had not been implemented by the end of the association with this company, although there was an intention to proceed with it (see section 6.6 results, feedback and next steps); this would mean that options for making environmental improvements are included in all three of the main methods for making Lean improvements within this company's Lean interventions (the three methods are by the checklist, by participants suggestions in the suggestions scheme, and by projects identified during kaizen blitz events, for example during mapping exercises and value stream walks).

Three methods by which environmental improvement actions can be generated are Continuous Improvement or Suggestions schemes, 5S checklists and projects generated from blitz events [I6-23]

6.5 Activities

6.5.1 Kaizen blitz event (including "Industrial waste" training and value stream walk)

Aims

Company B's practical aims in running the kaizen blitz event were to start the improvement process in the selected area and to train the participants (who were all new to the CSPS) so that they were empowered to make their own improvements and work in less wasteful ways.

The research aims were to observe the kaizen blitz event and note any discussions of environmental impact and attempts to reduce these impacts, or anything else relating to environmental impact reduction and the "environmental" additions to the program; also to observe how the trainers integrated the environmental impact reduction element into the program, how participants reacted to the addition to the training program, and whether they generated any environmental improvement suggestions or ideas for future impact reductions.

Procedure

The training consisted of two weeks of slide presentations, learning exercises and guided practical application of Lean tools and principles to begin improvement of the workplace. The aim is to provide knowledge and understanding, and also hardware (e.g. a suggestions board) and procedures for the participants to continue implementing Lean in their workplace. During the two weeks participants and trainers started making improvements and identifying improvement projects, which provides experience for the participants in the use of the tools, and brings the area up to a basic Lean standard.

Key features of note in the kaizen blitz event procedure were -

Part of the initial presentation introducing the participants to the kaizen blitz event was a discussion of the financial and other imperatives that meant that it was essential to make improvements.

A dedicated environmental impact training session was held at the end of the first week. The preparation of the slides for this was discussed in section 6.4.3 and examples are shown in Appendix C.

A waste walk was carried out at the start of the second week. Small groups of participants (around three per group) plus one of the black belts or the CSPST went to different areas of the shopfloor and walked sections of the process or value stream, looking for wastes at each stage of the process.

The production of present-state and future-state maps was an ongoing exercise throughout the two weeks. The wastes identified were recorded on the present-state map and a combination of these wastes and a prescribed reaction to some elements on the map was used to identify changes required for the future-state map (e.g. where there was parts storage, to use a kanban system to reduce the waste of inventory).

A lot of time was spent on presentations of training slides in the classroom, but there were also exercises and games which demonstrated the Lean principles or tools being taught, as well as guided activities where participants could try using the Lean tools under supervision.

Observations

Environmental actions during the kaizen blitz event

During the kaizen blitz event the environmental waste training session appeared to be well received and understood by the participants, but after that there was no more discussion of environmental issues unless it was initiated by the researcher. The trainers did not mention industrial waste in other training sessions, and in the practical exercises the researcher observed environmental wastes were not mentioned and the trainers did not prompt the participants to consider these types of waste. Participants did not themselves note any of these wastes or initiate discussion of them. The value stream walk provided an opportunity for participants to observe "industrial wastes" as well as examples of the other eight wastes in their workplace, but in practice none were recorded. The following sections give some possible reasons for this.

Reminders and examples

Early in the second week of the kaizen blitz event the researcher was talking with several of the participants and the subject of the "Learning to see Industrial waste" training was raised. One of the participants commented that the statistic comparing landfilled waste to the size of the Albert Hall had surprised him. This was in response to the researcher asking an open question about their reactions to the training. This suggests that **giving participants a way to visualise the environmental goals can help to make them memorable** [I6-24] – although, as noted above, remembering the goals was not translated into observable action to achieve them during the case study.

The prescribed format handed down from the corporate headquarters meant it was not possible to integrate the environmental points with the rest of the training. Trainers were using fairly detailed slides which ensured that common training was given to all participants within the corporation and were used by the trainers as cues to discuss certain points and give certain examples, but as no environmental content could be dispersed through these slides there was no cue to include the environmental wastes. Participants had cues to remind them to look for the "standard" eight wastes (for example pocket-sized cards with a list of the wastes and key Lean ideas) but none to remind them about the environmental wastes.

It was noted that the trainer accompanying the “waste walk” that the researcher observed was prompting the participants extensively during the early stages of the walk, initially by pointing out examples of wastes, but he did not give any environmental waste examples at this stage. The researcher mentioned a packaging waste but the participants did not record this. As the participants gained confidence in what they were looking for they began to make their own observations and referred to the “eight wastes” booklets they had been given, but they had no material reminding them of the “industrial wastes”.

If it had been possible to add environmental points throughout the training material (handouts, posters, slides, etc.) this might have helped participants to generate more environmental actions during the kaizen blitz event because it seems that **both participants and organisers need reminders to consider environmental goals** [I6-25]**.**

Suggestions

The researcher presented the “Learning to see industrial waste” training session (slides are reproduced in appendix C), which was the last presentation on the Friday of the first week. The participants were quite quiet during the presentation (maybe due to its timing or because they had not been introduced to the researcher before this session) but asked three questions at the end of the session when invited to do so. They wanted to know how company B compared to other companies in their environmental performance, raised an issue with packaging and commented on the distant locations from which the company imports some components, comparing this with “food miles”. The CSPST suggested in response to the last two comments that the participants who made them should record them as suggestions in the suggestions scheme that they were going to be introduced to later in the program – suggesting that **when prompted, participants can generate environmental improvement ideas** [I6-26].

Games, exercises and demonstrations

It was noted that the participants were much more engaged and participated far more during the exercises and games that were part of the kaizen blitz event, and also that the exercises and games seemed to help them to understand far better, so **an exercise or game that included**

demonstration of environmental waste identification might have helped them to look for these wastes [I6-27].

6.6 Results, feedback & next steps

6.6.1 Aims

The practical aim of these meetings was to provide a chance to reflect on how the implementation went and what was achieved. For the company organisers this was also a chance to discuss whether they would continue to implement the “environmental” additions to Lean, and if so, in what form.

The research aims were to investigate -

- What company B have done as a result of the implementation to reduce their impacts
    - How many suggestions with the capability to reduce environmental impact were made
    - Which of the proposed actions for improvement have been implemented and whether there are others that they plan to implement in future
    - How the implementation affected the environmental metrics
    - Were there any other environmental impact changes resulting from the integrated implementation
- Whether they will continue to integrate environmental impact reduction and Lean – what they will change, continue, stop.
- What they felt worked well

And to gather general comments and impressions on the implementation. To see what effect linking environmental impact reduction to Lean has.

6.6.2 Procedure

Feedback was sought at four separate meetings. The first was to gather feedback from the participants, and was held on the last day of the kaizen blitz event, a week after the environmental training was presented; the second was with BB3, to gather data about environmental suggestions and effects of the implementation; the third was with all of the organisation team who were free to attend, and the fourth was with the EHSM who was unable to attend the third of these meetings. The material presented and questions asked are presented below, for each session – responses to questions and material are presented in section 6.6.3 (Quotes and Observations), below.

Participants' questions

The participants' feedback session took the form of a fairly informal discussion, semi-structured around a set of questions, which were as follows –

- What three industrial wastes are (company B) focussing on?
- What do you think are the links between CSPS and industrial waste reduction?
- Have you any suggestions in mind or have you already made any SINCE the training, regarding industrial wastes?
- Had you made any suggestions regarding industrial waste BEFORE the training?
- How important do you think the issues (Company B) are focussing on, are? *
- How does this compare to your views on these issues BEFORE the training? *
- Any other comments?

* Responses to these questions were gathered using a linear scale for each question, divided from 1 to 10 and anotated so that 1 was "not important at all" and 10 was "very important" and participants were asked to mark a cross on the line at the importance level that matched their views.

Data gathering meeting

A meeting was held with BB3 to gather data on the results of the kaizen blitz event; how many suggestions were raised that would reduce environmental impacts, how many were being actioned, the prospects for any of the others being initiated at a later date.

Organisers' meetings

The organisers' meeting began with a presentation in which the researcher summarised the results relating to the integration of the environmental impact reduction with the kaizen blitz event, presented some suggestions for future implementation, and then gave some preliminary research findings. Organisers were then asked to comment on each of the points raised.

6.6.3 Findings

Effect of the implementation on environmental impacts

Goals 1 – 3 CO2 reduction, Reduction of "rubbish", Increase % recycled

In the amount of time the company was able to spend planning the implementation, it proved impossible to decide measures and methods of recording before and after figures relating to these goals, so no accurate assessment of progress on these goals was possible.

The EHSM reported a measurable reduction in diesel use due to "more sensible use of forklifts", but said that although he felt it was likely to be attributable to the environmental addition to the CSPS, it was not possible to say this was certainly the cause [EHSM, EHSM's feedback meeting, 11m 20]. He had also noted that where the CSPS had been implemented the participants were much more likely to turn off lights when not in use, both in tracks where the environmental additions were made to the CSPS and were they had not been [EHSM, EHSM's feedback meeting, 12m30].

Overall, it was found that **there was some environmental improvement as a result of the integration; it was not possible to measure impact reduction directly but the effect of those environmental impact reduction measures that were recorded would have been minimal at this stage** [I6-28]**.**

Goal 4 – Number of suggestions made

> *"certainly the team that I went round with on the waste walk which went to the* (x component) *store, and mentioned ah there's lights on that are running this thing, do we really need to run it? and there's the environmental waste impact if we decide to switch it off and do something different we could avoid that, so that discussion went on – so we did some environmental talk and on the waste walk, people did try to look for things. Did they go away and are now constantly thinking about it whilst they're at work? Probably not, but something changed on that one then, if you didn't do it before."*

[BB3, organisers' feedback meeting, 31m21]

Only one suggestion that directly reduced "industrial wastes" was made, which was to remove the component store BB3 mentioned in this quote. This was not made directly in order to reduce these wastes, but they helped to clarify the benefits and make the business case for implementing this change - reduction in energy usage was discussed with direct reference to the environmental training, and the likely reduction in impacts moved the project up the list of priorities and helped to justify it. In summary, **the environmental goals contributed to the justification of one project** [I6-29].

Some suggestions will probably have had a side-effect of reducing environmental impacts including those selected as goals, but this would not be the primary intent, and there was no mechanism to assess them [I6-30]. Examples of some such suggestions that were raised are: use of returnable packaging, but this is predominantly to prevent damage and for easier handling and stock replenishment; and to look at the preservative used on a component, mainly to avoid having to wipe the preservative off, but there would probably be environmental benefits. BB3 commented on the returnable packaging project, saying that it would have environmental benefits but these are not assessed or communicated because they are not part of the personal development plan (PDP) which sets everyone's goals for assessment (see 6.6.3.4 below), and this is also true of many other projects [BB3, organisers' feedback meeting, 24m30].

Many of the suggestions that came out of the kaizen blitz event were to do with issues of work balance and inventory, which need to be actioned urgently as they are having an obvious impact on ease of working and efficiency of the area. It seems likely that **actions to improve major impacts on the area's efficiency and ease of working would be suggested and completed before actions to reduce environmental impact** [I6-31]. The researcher's observations of the area during waste walks suggested that **it would be easier to identify environmental improvements once the major efficiency and ease of working improvements were made** [I6-32].

The EHSM was disappointed not to see more radical suggestions for environmental improvement and more independence in the participants, in making environmental changes [EHSM, EHSM's feedback meeting, 16m]; he felt that developing personnel who were knowledgeable enough in environmental issues and empowered to implement their own improvements was key to making more fundamental improvements, basing these comments on previous workplaces where Lean thinking had progressed further.

The number of suggestions generated from the kaizen blitz event for the non-environmental categories of waste was broadly in line with what the organisers would have expected [BB1 & BB2, organisers' feedback meeting, 58m45].

Views on the links, similarities and synergies between environmental impact reduction and Lean after the combined implementation

Waste

> *"To me it's that for me Lean and* (the CSPS) *are all about eliminating waste and the environmental push, if you like, is all about eliminating waste, it's as simple as that to me, that's the similarity"*
>
> [BB1, organisers' feedback meeting, 59m30]

> BB1 - *"I know we insisted it went down this format to align with* (the CSPS) *but I think it loses some of the impact by mixing it in with those wastes"*
>
> [BB1, organisers' feedback meeting, 50m15]

> *"For me the thing to really make it work would be to have an additional waste that was environmental, but obviously that's – it may happen long term, it may not happen"*
>
> [BB1, organisers' feedback meeting, 59m30]

The first quote is BB1's response to a request for organisers to identify the synergies between Lean and environmental improvement. He is quite clear that a key synergy is that **Lean and environmental improvement are both about reducing waste** [I6-33].

BB1 was unsure whether a ninth waste might be implemented, but felt that this would be a better method – opinion was divided among the other organisers, over whether this was feasible or advisable. The CSPST felt that the corporation would probably stick with additional environmental elements defined within some of the existing eight wastes rather than adding a ninth waste [CSPST, organisers' feedback meeting, 9m40] – due to the expense and difficulty of changing existing procedures and material. The CSPSC felt there might be a chance to suggest a change when the supporting paper-based material for the CSPS was being reprinted, for example, by feeding back the results of further trial implementation at company B to the corporate level [CSPSC, organisers' feedback meeting, 19m20].

It seems that **environmental waste can either be described to participants as an element of all the other wastes, or added and explained as another, individual waste, and there could be benefits to either option** [I6-34]; adding another waste might help to remind participants and organisers to look for these wastes, but drawing out the environmental elements of the existing wastes might help with integration and reinforce the idea that environmental improvement is desirable for its own sake and because it can help companies save money and become more efficient.

Wasteful and value-adding activities and environmental improvement

> *"The guys out on the line, and some of the operations management team really, are constrained by the bits of equipment that they've got, so there's no point them having a metric to reduce the energy consumption of a particular machine because that's given to them – maybe the logic is more as we're doing new capital introductions there is a metric there encouraging the most efficient machine that we can, the most energy efficient I guess as opposed to trying to do it after the fact and improve the machine we're stuck with"*
>
> [BB1, organisers' feedback meeting, 25m50]

While it is true, as BB1 comments, that there is probably little that can be done about machine consumption, participants could be encouraged to look for other wastes of energy, for example where machines are programmed to make unnecessary movements or are over-processing, are using energy while waiting for a previous process, or where fork-lift trucks are transporting parts further than necessary and using fuel. These are closely linked to the standard wastes, but **companies may need to be encouraged to look for the waste of energy in wasteful (non-value-adding) activities rather than value-adding core processes** [I6-35].

It was difficult to be clear over the course of the kaizen blitz event whether the actions resulting from the CSPS are focussed on capital investment more than on small incremental low-cost changes, but throughout the case study it seemed that there was a tendency to think that energy usage was inextricably linked with machine specification – and this was much more of a problem for energy than the other environmental impact goals. This may have been due in some measure to the tendency to break down a value stream by work station leading to a focus on the work done at that station rather than in between value-adding steps.

Holistic thinking

> *"Because the guys working it, it should be part of their… it should be integral, it joins, it's not separate. For me, you can't separate this out – from your experiments it would appear that that's totally correct, it just affirmed that for me, that that is the way to do it. It is joined, it's not separate. Everything is in sustainability, in my thinking – it's those simplistic decisions that are made, through the culture of avoiding waste – that's the challenge."*

[EHSM, EHSM's feedback session, 19m]

In context, what the EHSM is saying here is that **Lean decisions can reduce or increase environmental impacts and changes made to reduce environmental impacts will have impacts on Lean** [I6-36]; the two kinds of improvement are inextricably linked. It is interesting that this is a view he was forming before the integrated implementation, and that the implementation has reinforced this view.

What worked, and what did not work?

Effectiveness, mindsets & understanding

> *"I like the industrial waste presentation, I do think people are buying into it, but I'm not seeing enough of the safety observations going in and environmental observations, that's not too good, and environmental corrective action, I'm not seeing too many of those as yet – hopefully that will develop, we've still got some work to do on that."*

[EHSM, EHSM's feedback meeting, 6m30]

The EHSM is suggesting that the environmental training in the integrated implementation had some effect in raising understanding but this has not yet been translated into actions [I6-37] – suggesting that the awareness-raising part of the training is effective but other elements of the integrated implementation designed to incite actions might require modification. Some ways to do this, as suggested by organisers, are set out below.

Champions & Integration

> BB1 – *"maybe the way we do it is the way – in the past the safety training was always done by the safety team, wasn't it…*

….maybe that's what we do for the environmental stuff, that (the EHSM) *comes in and does the training and supports on the waste walk"*

BB2 – *"and I suppose from the point of view of the champion thing, that* (CSPSC)*'s said to us, you know, we'll add in a requirement for us here to come up with two environmental savings during a* (kaizen blitz event)*, well that's us then having to champion it and that's the right way to do it because there's a measure against us"*

[BB1 & BB2, organisers' feedback meeting, 1h04m10]

EHSM - *"we've got champions in the Health and Safety and we're going to link them in more, but about specific waste champions well if we then choose to add that energy to it then fine."*

Researcher - *"Is that linked into* (the CSPS)*?"*

EHSM - *"We're trying to integrate the whole lot, so it's in* (the CSPS)*, so it's engrained in the culture. So the energy piece, we want everyone involved in the energy, we want everyone involved in segregation* (of waste streams), *we've taken people from all over the business so it's not just* (the CSPS) *but we will fundamentally use the* (CSPS) *role to champion it within the workplace."*

[EHSM & Researcher, EHSM's feedback meeting, 2m30]

The EHSM is not satisfied with the levels of integration, saying that he had not had any contact with the CSPS team other than to talk about training and provide some energy usage example data [EHSM, EHSM's feedback meeting, 7m30 & 4m].

Later in the feedback meeting, he mentioned running training on energy usage and mentioned wastage of energy but had not considered involving the CSPS team although when asked, indicated that he was willing to do so [EHSM, EHSM's feedback meeting, 10m]. He also mentioned the possibility of the EHS team running their own waste walk, possibly with the CSPST [EHSM, EHSM's feedback meeting, 9m].

Throughout the implementation the organisers seemed positive about the idea of integration and could see benefits in integrating, and the two departments worked well together to generate ideas, yet there was still little integration between the departments unless the researcher instigated it. It seemed that **integrating environmental improvement aspects into the kaizen blitz event did not cause the Lean and environmental departments to work more closely together** [I6-38], even though there were times when the CSPS team needed input from the environmental department to help with this implementation (see “Selection of measures” below – it was difficult to select measures that would drive the desired behaviour, because the CSPS team were unsure of what behaviour should be encouraged in order to meet their top-level goals).

The idea of having a champion for the environmental improvement element of the CSPS was proposed by the researcher during the feedback sessions. The aim behind this suggestions was that the champion would ensure good communication between the EHS and CSPS departments (in particular to ensure that each department knew about any events, initiatives or changes the other was planning, especially those that would affect shopfloor areas) and would look for opportunities to include environmental elements in the Lean activities.

In discussing the suggestion, BB1 cited an example of closer links with the health and safety part of the EHS department so there is a precedent for this, and having the EHSM present on waste walks would seem to answer a part of the need for the champion, and as well as benefiting from the EHSM’s environmental expertise on the waste walk, this might have a side-effect of building better links between the departments. BB2 is suggesting that by providing a requirement on the CSPS team to produce improvements from the CSPS events, they would in effect all be champions; this is reasonable, as is his point that having a measure against them means it is right that it is their responsibility to act to fulfil that measure. The EHSM seems to be open to integrating the CSPS team with his department, but it did not appear that this was something he had thought of before being questioned by the researcher and this was echoed in the later comments reported above – the energy training would seem to be ideally suited to integration with CSPS but it did not seem to have occurred to him to initiate the integration from his department.

Having a designated champion for the environmental element was not popular however; BB1 did not feel it was necessary, pointing out that they did not have champions for other elements (e.g. health and safety). It seemed that the perception was that **assigning an environmental champion within**

the CSPS might lead to an excessive focus on environmental improvement [I6-39].

Selection of measures

> *"I think that will be the biggest challenge because we can teach people about environmental wastes as it were but what does it mean to the guys working turbos? It's going to be really hard to granularise that so that they can understand, because a lot of the things we're driving towards are at the value stream level… … if I have an operator in turbos, what would the measure be for him to do something"*

[CSPST, organisers' feedback meeting, 24m45]

> *"Maybe the lowest we can go is the value stream level for some of these things – I don't know"*

[CSPST, organisers' feedback meeting ,27m10]

> *"I think that's really going to be our biggest challenge is figuring out what the measures are because that's going to drive accountability – at the macro level, we're ok, but at the micro level that's more of a challenge"*

[CSPST, organisers' feedback meeting, 29m]

> *"sometimes we can forget that we need to get the senior managers aware"*

[EHSM, EHSM's feedback meeting, 6m]

> *"you could have a tally chart in each area showing how many bins are getting emptied each week or day, and how many of the recyclable bins are getting full each day versus how many of the general waste"*

[CSPSC, organisers' feedback meeting, 27m45]

These quotes are a continuation of the theme begun during the planning meetings; what it is possible to measure, at what granularity, the cost and value of such measurements, and how they will drive behaviour change. Company B were very keen to be clear on what behaviour they wished to drive before deciding on the measures they would use, but did not have clear ideas of desirable environmental behaviours that they might drive, due to the lack of a strong environmental presence on the planning team, so the matter was left unresolved. After the preliminary implementation there were some clearer suggestions which are set out below (see 6.6.3.4), but these were not discussed with the EHSM [EHSM, EHSM's feedback meeting, 4m].

The final quote is an attempt to find a simple practical answer to the problem of setting a measure and communicating it in a way that shows employees how their actions contribute to the team performance being measured and drives the desired behaviour (in this case, overall waste reduction and increase in percentage separated out for recycling). Reporting by "binfulls" seems very visual and it would be easy for employees to see what they need to do to improve. At the EHSM's feedback meeting around a month later, the EHSM reported that percentage of waste segregated for recycling was going to be recorded on team boards [EHSM, EHSM feedback meeting, 1m30], but he did not clarify in what format the reporting would be done.

These quotations provide further evidence for the following findings suggested at the planning / goal and measure selection stages:

- I6-5 Setting suitable measures and targets for operators at all levels in the company proved much more difficult than deciding on top-level goals
- I6-6 Goals selected for any given role must be those that someone working in that role could reasonably be expected to achieve
- I6-7 measures must be selected to drive desired behaviour changes.
- I6-9 Measures selected should be achievable at the local level at a cost that is deemed reasonable, so that participants' progress towards the goals is visible and can receive recognition
- I6-13 Measures should be selected with the aim of driving behaviour that achieves the overall goals

Prediction of effects

> BB4 - *"on the original switch off and save we took it down to one light on an area, and the cost of running the light – so we actually gave – like track one, how much by turning their lights off between shifts and that – I think we went down as far as that"*
>
> BB1 - *"so just using an example of the lights being left on, how much they cost…?"*
>
> BB4 - *"…lights, leaving a fan on over break-time, leaving a fan on at end of shift, so by bringing in a champion, how much a*

week, month, year we were saving and how that would affect things - I'm sure we can get that far"

BB2 – *"I mean can we go down to print-outs? Do we need to print so many pages?"*

BB1 – *"wasted paper, yeah…"*

BB2 – *"yeah stuff like that, you can personally affect it by not doing – you know, by not doing a print out, if you share a print out when you're in a meeting rather than all having one, or even if you do it two to one… how you can affect that personally, is where you really need it, and just a list of that."*

BB1 – *"Yeah, good point, it's examples isn't it?"*

[BB1, BB2 & BB4, organisers' feedback meeting, 51m30]

BB4 also said that improvements have been made and recorded (e.g. as a result of the switch off and save project) but just not reported widely, so few people are aware of what has been done [organisers' feedback meeting, 1h01m40].

This quote shows that there is a precedent for reducing energy usage and an ability to measure or predict the effect of changes or suggested improvements. Prediction of effects is slightly flawed, in that there might be unexpected side-effects of actions which either enhance or counteract the expected improvement, but then direct measurement is also difficult as it is hard to calculate and deduct the effect of other factors (notably variation in throughput). The key point the Black Belts are making is that **providing participants with information about the effect of their individual actions can help to drive behaviour change** [I6-40].

Examples

BB1 – *"just some examples I suppose"*

BB2 - *"how can we affect it, like you did the previous slide, you showed the turning the lights off and stuff like that – how can we affect it personally, that's what we need"*

BB1 - *"so we can we take them through what we want them to look for, when we go out onto the op station "*

[BB1 & BB2, organisers' feedback meeting, 50m30]

Examples have been discussed in some sections above.

BB1, BB2 and BB4 discussed examples used during the switch off and save campaign, where participants were given information on the cost of running lights or appliances for varying amounts of time, and how this could help participants relate impacts to their own actions [BB1, BB2 & BB4, organisers' feedback meeting, 51m30] – see Predicted effects, above). They felt that this was a helpful thing to do, suggesting that they might help people to begin considering similar and other changes they could make and the effects of their actions. In this case the examples were given in financial terms and it seems that the saving for the company encouraged participants to be more careful about turning off lights and fans when they were not needed. The EHSM reported at his feedback meeting that he had provided this data to the CSPS team at their request [EHSM, EHSM's feedback meeting, 7m30], which suggests that they will be implementing this idea.

The CSPSC noted that once this was in place, later kaizen blitz events could use suggestions generated in earlier ones as their examples [CSPSC, organisers' feedback meeting, 45m25].

It seems from these comments that **examples are important because they help participants to see what is expected of them** [I6-41] and how they can relate the goals to their activities (supporting [I6-40] see predicted effects, above) – but also that **examples can be helpful to the organisers and participants in showing them environmental wastes they can start looking for on a first waste walk** [I6-42].

Reminders

> *"I think it'd be very easy to forget about it if we just followed that process – because it's that prescriptive and you just get into the thing of just following that prescription"*
>
> [BB1, organisers' feedback meeting, 42m15]

> BB2 - *"the emphasis with sitting there with those on display all the time, emphasising the waste we're looking for, and the environment isn't on there –what kind of message does that send?*
>
> BB1 - *"Well if you did it on the local boards as a local measure – then their minds will be on it"*
>
> BB2 – *"but then again, what are you measuring? That's the key, what are you measuring?"*
>
> [BB1 & BB2, organisers' feedback meeting, 1h01m]

In the first quote BB1 is responding to the researcher's suggestion that there was a need for reminders to be integrated into the kaizen blitz events and into the normal working environment, for both participants and trainers. He agreed that it was difficult for trainers to remember to mention the wastes, and this was particularly so when they were using the prescribed training material from the parent company which tells the trainer exactly what to present but does not include the proposed environmental additions.

He was also open to the idea of producing environmental reminder cards to use on waste walks [BB1, organisers' feedback meeting, 48m30 & 57m] (see future plans section).

The second set of quotations also comments on the need for environmental goals to appear to participants to have equal weighting with the other goals. Putting some environmental measures on the team boards would help to remind participants about these wastes and show that they are considered important. It seems that this is being put in place, because the EHSM stated during his feedback meeting that each line's recycling rates were being put on boards ([EHSM, EHSM's feedback meeting, 1m30], see selection of measures, above).

The feedback meetings confirmed the previous finding that **both participants and organisers need reminders to consider environmental goals** [I6-25].

Future implementation of "environmental impact reduction and Lean"

At the feedback meetings the organisers made the following propositions for the future of the integrated implementation.

Future of integrated implementation at company B and Corporate adoption

During the organisers' feedback meetings, the suggestions about changes to the method of integrating environmental improvement into the CSPS were made in the context of an intention to continue with the integrated implementation.

Having run a trial of the corporate structure company B have got permission to modify it somewhat. They plan to carry out implementation stages over a longer period and do more kaizen blitz events focussed on a smaller area with less people, and prefer a less prescribed structure, less classroom training and more emphasis on practical guided application of the tools in the workplace, presenting a maximum of around a dozen slides then "get out there and do it". During this discussion, BB1 suggested including just a few environmental slides with the general Lean waste training then doing a waste walk to identify the wastes that have just been explained in the participants' work area, using environmental reminder cards alongside eight waste cards [BB1, organisers' feedback meeting, 48m30 & 57m] in line with the new format.

After the case study, Company B are planning to continue implementing together, and see scope for corporate adoption [I6-43]

Prioritise environmental action by including environmental goals as part of Personal Development Plans

(The Personal Development Plan or PDP is what an employee's performance is appraised on)

> *"I think it's key to getting environmental stuff in, I think the absolute critical bit to me is creating some measures that then roll down to people's PDPs that you're actually going to deliver this on, because until you get that people can quite easily just drop it as soon as the stuff that is in their PDP needs doing… …so unless there's something that's going to drive their activity – it's along the lines of what we're doing with (the CSPS) because we have to kind of bring people along and build capability until it becomes the norm and part of their culture because at the moment it's probably not. I mean there's probably some people out there who think about the environment all the time because they're really into it, but there are probably a lot out there who probably don't, certainly while they're at work"*

[BB3, organisers' feedback meeting, 19m50]

> *"…peoples' focus goes elsewhere and people want to just focus on the one, two or three things that are in their PDP, so the only way to do it is your point (BB3) is to get it embedded in all the metrics boards and cascaded across all the sites, down through all the sections and all the value streams down to each line and then the relevant leaders have it in their PDPs as well, then you're starting to get some integration and starting to get people on the hook for it. And then they start to get interested and then they start to ask for more help. Because they've got these goals and challenges and they're not quite sure how to do it, so they*

come asking for help – so you're building that infrastructure to make it happen."

[CSPSC, organisers' feedback meeting, 21m40]

This suggestion would allow company B to drive behaviour and show employees that they are committed to making improvements. Addition to PDPs gives the clearest message that everyone is expected to act on environmental issues. It also shows that **the organisers think the environmental goals are important** [I6-44] – they are setting them among the three or four things that the company must do, if it does nothing else.

However, they are also showing that these goals need to be enforced. It is not completely clear whether this is simply a function of the number of goals, which is too large for all to be met, and they are simply picking the ones that are most important to enforce; or whether it is because the goals are new, therefore more likely to be overlooked (this is implied by BB3 in the first quote above [BB3, organisers' feedback meeting, 19m50]); or they think these goals are particularly likely to be ignored, or are particularly difficult to meet, or some other reason. This does not negate I6-44, because if the organisers did not feel the goals were important, they would not include them with the

"one, two or three things that are in their PDP"

[CSPSC, organisers' feedback meeting, 21m40]

The final quote, from the CSPSC, suggests that adding this as a target would drive people to "pull" information they did not possess from relevant sources on how to fulfil the targets – so this could be a bottom-up process that is driven by participants.

Set a number of environmental suggestions per kaizen blitz event

CSPSC -"*You know on the* (kaizen blitz event) *process now, the deliverable sheet – you have to have the five quality improvements and the five safety improvements - simplistically, if we did nothing else other than say there's got to be two environmental improvements for every* (kaizen blitz event) – *what do you think that would drive? If we just did that and nothing else?"*

BB1 - *"Two environmental improvements for every* (kaizen blitz event)*!"*

CSPSC - *"Yeah, but it would force people to think of some of those improvements, which would get the dialogue going…"*

[CSPSC & BB2, organisers' feedback meeting, 32m 15]

CSPSC - *"Knowing full well as we do in* (kaizen blitz events) *that we're looking for five safety improvements gets you to look at that so as you're talking about, well what wastes have we got, what issues can we resolve… people start to think about that, so if we said we want two environmental improvements, they'd say well, what do you mean? (so you would) Pull out some examples… (then they would say) "oh right, let's go and have a look"…"*

CSPST - *"That's the key – have some examples and some way to measure it, that's really the key, because if we say we're doing something environmental without having a baseline well where are we going from there?"*

[CSPSC & CSPST, organisers' feedback meeting, 33m30]

"From the next (kaizen blitz event) *onwards we can say we're doing that* (expecting two environmental improvement suggestions raised for each kaizen blitz event)*"*

[CSPSC, organisers' feedback meeting, 35m30]

"we can at least do something about choice of metrics for next year – if we choose to do this, now is the right time of year; we can start by simplistically putting an expectation on ourselves that we want two environmental improvements for every (kaizen blitz event)*, we can get that going and use some of these examples - so there's things we can definitely do off the back of this."*

[CSPSC , organisers' feedback meeting, 45m25]

BB2 agreed with the idea of a target of a number of environmental improvements, as they do for safety, because that would make people think about it; CSPST said that the difference was that safety is personal to operators, there is a need to explain the importance of CO_2 [BB2 & CSPST, organisers' feedback meeting, 46m30]. The EHSM agreed that setting a target for environmental actions from kaizen blitz events was a good idea [EHSM, EHSM's feedback meeting, 6m45].

These quotes show that the organisers believe **setting a requirement for the generation of a given number of environmental improvements from each kaizen blitz event would be an effective measure** [I6-45]; this measure does not specify a required scale for the improvements (so they could be quite small ones) but it seemed that simply giving participants some time and encouragement to focus on these issues during their feedback session allowed them to produce plenty of improvement ideas.

This suggestion would allow participants more scope to act on environmental wastes they observe, whereas some other suggestions (such as an environmental checklist) are more restrictive – they might work particularly well alongside one another. This concept of providing goals for environmental improvement then supporting participants when they ask for help to achieve them is also mentioned by the CSPSC with respect to adding environmental goals to PDPs, above [CSPSC, organisers' feedback meeting, 21m40]

Install line level electricity usage meters

The EHSM also commented during his feedback session that meters to measure electricity usage at the line level were going to be introduced [EHSM, EHSM's feedback meeting, 1m45]. This would make it much easier to set operators measures and targets relating to the top-level goal of reducing CO_2 emissions.

Participant reactions

Participants' feedback

Candidates could see a link between the CSPS and environmental impacts (although the discussion at this point was dominated by one voice). Participants also remembered the selected measures with only a little prompting.

Participants reported that they felt these issues were important (and remembered some of the illustrative points made about UK waste levels etc. Before training participants ranked the importance of environmental issues with a spread of responses between 6 and 9 out of 10, where 1 was "not at all important" and 10 was "very important" and the training seemed to make them think these issues were more important (spread of responses between 7 and 10). However, the first response was by a team leader who ranked these issues highly so there may have been an element of peer pressure here.

The post-training feedback session suggested that the training had been effective in explaining the targeted environmental issues and making them memorable [I6-46].

The learning from the training did not generate many actions to reduce environmental impacts, but with prompting the participants generated some environmental impact reduction suggestions (although they didn't subsequently record these, despite being prompted to do so); there was a lively discussion in this section of the feedback session. None of the participants reported making any suggestions for environmental impact reduction during the kaizen blitz event, but on prompting they recalled three suggestions that had already been made and generated four that they would suggest (although these included trying again on some of the previous suggestions or variations on them). This supports findings I6-26 (When prompted, participants can generate environmental improvement ideas) and I6-25 (Both participants and organisers need reminders to consider environmental goals) – the latter is supported because participants produced the suggestions when prompted but had not done so before.

6.7 The negative case

A method for minimising bias is to actively look for evidence that disagrees with emerging themes within research, and to ensure that the research findings takes these negative cases into account. The researcher has done this throughout the research. In this phase, the negative cases were sought out during the original pass through the data and once again after completing the main process, in the second pass the researcher specifically sought out negative comments. The following negative cases are identified for this phase.

Firstly, the difficulty in assigning useful goals and measures meant that the effects of the integration had to be assessed from the suggestions and project proposals which meant that it was not possible to be really sure what had changed as a result of the additions to the implementation. The company treated this implementation as a pilot study in order to work out how to set goals for shopfloor staff that were relevant to their work and fulfilled the top-level goals. At the end of the case study they had come to the conclusion that they should do this by setting a target number of environmental improvement projects that should come out of each kaizen blitz event.

Secondly, and linked to the first point, is that the reported actual changes that could be directly attributed to the additions to the implementation were quite small at the end of the case study. As stated in section 6.6 the actual environmental impact reduction reported for the implementation was not very great. The section gives some suggested reasons why this might be so (the early stage of the implementation, the difficulty of measuring and reporting impact reduction, and the need for better examples and more reminders about environmental improvement). The company was discussing ways to improve the integration in future which might address these issues.

It should also be noted that measurement would have its own problems (it can be difficult to assign changes to eliminate the effect of other changes for example changing production rates or weather conditions can affect electricity consumption).

The nature of the research questions chosen meant that the company reactions to the concept were of more interest for this research than numerical data about what changed, and in fact the difficulty that the company had in setting measures and goals was an interesting finding in itself. The findings drawn reflect these points (for example, I6-28 There was some environmental improvement as a result of the integration; it was not possible to measure impact reduction directly but the effect of those environmental impact reduction measures that were recorded would have been minimal at this stage; I6-37 The environmental training in the integrated implementation had some effect in raising understanding but this has not yet been translated into actions; I6-5 Setting suitable measures and targets for operators at all levels in the company proved much more difficult than deciding on top-level goals).

One of the organisers expressed some doubt about the compatibility of Lean and environmental improvement during the planning stages –

> *"By measuring time and that you'll get better green metrics by doing it quicker, but you're also contributing to over-production"*
>
> [BB2, metrics meeting, 17m35]

This did not prove to be a problem during the implementation phase and was only mentioned this once by this organiser, and not at all by others. It seemed that integration would encourage consideration of all factors together, so this incompatibility should not arise.

Two suggestions were made which the company did not adopt during the case study. The first was the addition of environmental impact indicators to value stream maps. Concerns were raised about the difficulty of adding metrics to the maps, and the difficulty of doing anything as a result of the information that would be gained, and the company did not implement this modfication. The second was the suggestion of a champion to guide integration of environmental improvement with Lean; the company was concerned that an environmental champion might cause the implementation to focus too much on the environmental improvements, to the detriment of the original Lean ideals. This is reflected in I6-39 (assigning an environmental champion within the CSPS might lead to an excessive focus on environmental improvement).

One prediction made was that integration of the ideas of environmental improvement and Lean might help the closer working of these two departments or functions, which proved not to be the case (I6-38 integrating environmental improvement aspects into the kaizen blitz event did not cause the Lean and environmental departments to work more closely together). Finding I6-16 (there is potential for better integration of Lean and Environmental departments or functions to generate better solutions to problems through the application of different sets of knowledge, responsibility and ways of thinking) still applies however; there is potential for the departments to work more closely together, and there could be benefits should they do so, but simply integrating the implementation is not sufficient to cause departmental integration.

6.8 Chapter findings summary

In this section the findings from this chapter are grouped according to the research question whose answers they will inform.

Research question 1 - If there are synergies and similarities between Lean and environmental improvement, what are they?

I6-1 A key aim of Lean is to empower the workforce and encourage ownership of processes and their improvement, and both Lean and EHS staff perceive that this could also be beneficial in environmental improvement

I6-14 Value stream thinking might be used to help operators understand the environmental impacts of their operation and its value stream

(Future work - Operators should understand environmental impacts of their operation and its value stream.)

I6-15 Operations cards used by operators to follow standard work procedures could also include environmental inputs and outputs of the process

I6-17 There are environmental impacts associated with the other eight wastes

I6-33 Lean and environmental improvement are both about reducing waste

I6-36 Lean decisions can reduce or increase environmental impacts and changes made to reduce environmental impacts will have impacts on Lean

Research question 2 - How can the synergies between Lean and environmental improvement be used to inform integrated implementation?

I6-7 Goals selected for any given role must be those that someone working in that role could reasonably be expected to achieve

I6-8 Shopfloor goals need to be related directly to shopfloor actions rather than more abstract top-level goals

I6-9 Measures selected should be achievable at the local level at a cost that is deemed reasonable, so that participants' progress towards the goals is visible and can receive recognition

I6-10 A definition of environmental waste might be helpful to an implemented integration

I6-11 The definition of environmental waste might begin with the concept of the appropriate use of resources

I6-12 Value of environmental improvement to the customer is not yet defined

I6-13 Measures should be selected with the aim of driving behaviour that achieves the overall goals

I6-18 The environmental impacts to target using Lean methods should be those that occur in non-value-adding activities

I6-20 Participants need to learn to see environmental waste as well as lean waste

I6-23 Three methods by which environmental improvement actions can be generated are Continuous Improvement or Suggestions schemes, 5S checklists and projects generated from blitz events

I6-27 An exercise or game that included demonstration of environmental waste identification might have helped them to look for these wastes

I6-34 Environmental waste can either be described to participants as an element of all the other wastes, or added and explained as another, individual waste, and there could be benefits to either option

I6-35 Companies may need to be encouraged to look for the waste of energy in wasteful (non-value-adding) activities rather than value-adding core processes

I6-45 Setting a requirement for the generation of a given number of environmental improvements from each kaizen blitz event would be an effective measure

Research question 3 - What happens when Lean and environmental improvements are made together?

I6-2 Getting more benefit from activities they were already involved in was an attractive feature of integrating environmental improvement with Lean

I6-3 Integration has the benefit of reducing the number of different initiatives in the factory

I6-4 The concept of integration and the proposed structure is quite easy to understand

I6-5 Setting suitable measures and targets for operators at all levels in the company proved much more difficult than deciding on top-level goals

I6-6 Terminology selected must be clear and unambiguous in the context of the company, and must fit in with their Lean and other in-house terminologies

I6-16 There is potential for better integration of Lean and environmental departments or functions to generate better solutions to problems through the application of different sets of knowledge, responsibility and ways of thinking

I6-19 Terminology used must be consistent and reflect the corporate requirements

I6-21 Participants need to understand the importance of industrial environmental impact and how their actions are important in reducing it

I6-22 Examples are memorable and can make the training more personal

I6-24 Giving participants a way to visualise the environmental goals can help to make them memorable

I6-25 Both participants and organisers need reminders to consider environmental goals.

I6-26 When prompted, participants can generate environmental improvement ideas

I6-28 There was some environmental improvement as a result of the integration; it was not possible to measure impact reduction directly but the effect of those environmental impact reduction measures that were recorded would have been minimal at this stage

I6-29 The environmental goals contributed to the justification of one project

I6-30 Some suggestions will probably have had a side-effect of reducing environmental impacts including those selected as goals, but this would not be the primary intent, and there was no mechanism to assess them

I6-31 Actions to improve major impacts on the area's efficiency and ease of working would be suggested and completed before actions to reduce environmental impact

I6-32 It would be easier to identify environmental improvements once the major efficiency and ease of working improvements were made

I6-37 The integrated implementation and environmental training had some effect in raising understanding but this has not yet been translated into actions

I6-38 Integrating environmental improvement aspects into the kaizen blitz event did not cause the Lean and environmental departments to work more closely together

I6-39 Assigning an environmental champion within the CSPS might lead to an excessive focus on environmental improvement

I6-40 Providing participants with information about the effect of their individual actions can help to drive behaviour change

I6-41 Examples are important because they help participants to see what is expected of them

I6-42 Examples can be helpful to the organisers and participants in showing them environmental wastes they can start looking for on a first waste walk

I6-43 After the case study, Company B are planning to continue implementing together, and see scope for corporate adoption

I6-44 The organisers think the environmental goals are very important

I6-46 The post-training feedback session suggested that the training had been effective in explaining the targeted environmental issues and making them memorable

6.9 Chapter conclusions

This chapter has set out the data gathered during the planning, implementation and feedback meetings of a Lean Kaizen blitz event. The planning included discussions about training, goal setting and the selection of suitable measures. Key stages in the implementation were training participants to recognise and deal with Environmental wastes, practical exercises and waste walks, and the gathering of continuous improvement suggestions.

The key findings are presented along with associated discussion and the evidence that lead to these findings, in order to show that they are reasonable.

The key findings are presented in sections 6.4, 6.5 and 6.6, along with associated discussion and the evidence that lead to these findings, in order to show that they are reasonable.

Interim findings from this case study are drawn from company decisions and organisers' comments during the planning stages, participant reactions during the training and early supervised implementation, participant, organiser and trainer feedback sessions and the results and effects of integrated implementation.

As a result of the case study, some direct effects of the integration of environmental improvement with the Kaizen blitz eventcould be reported, but at this stage they were not very extensive. The involvement of the workforce, and the best methods to train and motivate them and provide incentives to act, continued to be important. The company reported that the integration had been successful in raising levels of awareness among the participants. Goals and measures were seen to be very important, but although organisers were clear on the top-level environmental impacts to target and the criteria for selection of goals for the workforce that would fulfil them, it proved harder than expected to find goals that fulfilled them. The importance of examples and reminders to act were themes that emerged during this case study. Overall, the company response to the integration was positive and they were planning for continuation of the integration, with modifications and improvements (for example, maintaining the selected top-level environmental goals but setting a target number of improvements for each Kaizen blitz event, rather than a numerical goal related directly to the top-level goal).

Section 6.9 presents all the interim findings for this case study, grouped by the research questions whose answers they inform. Bias avoidance techniques used are discussed in section 6.3.1. Section 6.7 sets out the negative cases.

7 Case study 2

Chapter Overview

This chapter of the thesis explains how the second case study was carried out and presents the findings from it.

The chapter begins by explaining the aims of the chapter and of the case study, then gives some background information about the company and the people whose input was most important during the case study. The chapter then goes on to outline the action research structure used in the case study.

The main part of the chapter explains each stage of the case study, beginning with planning stages, then activities, then feedback stages. The section for each stage begins by explaining the aims for the stage, then the procedure that was followed, and finally the findings from that stage (which includes quotations, if appropriate, and responses to the research aims). The quotes presented in these sections were statements made by organisers, participants or trainers during the section being discussed, and were selected because they supported emerging themes or contradicted them, presented new and relevant ideas or information that might be the initiator of a theme, or were particularly strongly or emphatically expressed or given high importance by the speaker.

The chapter then goes on to deal with quotations that represent the "negative case" (those that go against the findings developing in the rest of the chapter) and considers what might be applicable outside the case study company.

Finally the findings generated in this chapter are summarised, with reference to the chapter aims.

Chapter aims

The chapter will explain how the case study proceeded, the data and findings gained from it, and how they can be interpreted. The chapter will show that the data summaries are accurate and that the findings are reasonable (i.e. that another researcher might reasonably have been expected to draw the same conclusions from the data), and will point out how bias was avoided. It will also present and explain any data that disagrees with the emerging patterns or contradicts other data or findings.

Notation used in this chapter

The notation used in this chapter is as follows:

- Interim findings are given as statements that answer one of the research questions. They are highlighted using bold text, and given a reference number afterwards in the form [I7-x], where x is the finding number, allocated according to order of appearance in the chapter's text.
- Quotation references or references to points made during a meeting that was recorded are formatted as [person, meeting, time]. For quotations, these references are situated on the next line and to the right. People are referred to by the abbreviations as allocated in section 7.2.2.

7.1 Aims of Case Study 2 – Company H

This second case study aims to shed light on the research questions by intervening in a Lean implementation in a company and using action research methods to observe the effects of the intervention. In this case the intervention is in the form of explaining to the company managers the tools developed as a result of the data gathered during the literature review and interviews, as described in chapter 5, and then providing assistance for them to apply the tools that they choose.

Thus far the aims are the same as those for Case Study 1 (chapter 6) but Case Study 2 aims to build on the findings from Case Study 1 and investigate the effects of differences in the implementation methods. Section 7.3.1 highlights changes from Case Study 1 that were investigated (in summary these were better integration of environmental additions into the training, training presented by a single trainer, more prompting of participants during the waste walk, addition of a ninth waste of "environmental impact" rather than highlighting the environmental elements of the existing eight wastes).

7.2 Background

7.2.1 Company background

The company is an SME and has been in business 75 years, selling high-end standard and bespoke products. It is privately owned and the owners are all on the management team in various capacities. The evolution of the company was initially quite organic, from “a couple of guys in a garage” which expanded to a couple of industrial units; at this stage there was a recognition that the company needed to recruit someone with knowledge and experience of more formal management methods, and this coincided with initiation of plans to move to a purpose-built site. The Operations Manager recruited as a result of this realisation brought with him knowledge and experience of Lean methods, among others, which was new to the company but contributed to the filling of the gap they had perceived. Subsequently understanding of Lean within the company has been gained from the Operations Manager and by sending other managers on training courses, and by some help from an external Lean training organisation that the Operations Manager knew from previous roles. It was important that the trainers would work by “doing interesting things with the people who work on the shopfloor”. The company tends to avoid buying in to “management fads” and there is a dislike of the use of jargon, or a lot of procedures for the sake of procedures – there is a natural inclination to simplify.

Environmental and social equity are quite important to the company because of the owners’ principles, but these principles are applied in a quite pragmatic manner, as they are in business to make money. During the interview phase the respondent for this company was quite clear that there was the potential for financial benefit from environmental improvements.

The company does not have a separate EHS department and responsibility for environmental compliance etc. lies with the operations department.

7.2.2 Participants

Company Organisers

Interaction with the company during the planning phases was with two members of their management team – the Managing Director (referred to as MD) and Operations Manager (referred to as OM). The MD was promoted to that role part way through this study and the previous MD was also present at the second initial meeting. He is referred to as PMD.

- OM – The OM was promoted to this position having previously been the stores manager. He had completed some in-house Lean training prior to the implementation and had some personal interest in environmental issues which meant that he was somewhat informed about environmental impacts and their reduction.

- MD – the MD had experience of Lean from prior employment in the automotive manufacturing industry. He was employed by company H when they felt that they needed to recruit someone with more knowledge and experience of manufacturing although at this stage the company were not aware of Lean – this was something that he introduced to the company.
- PMD – the previous MD had some understanding of Lean ideas. He seemed to have a firm conviction that it made financial sense to reduce environmental impacts, for example when they were moving to a new purpose-designed factory, renewable energy and windows that maximised natural light in the factories and offices were important in the specification as he foresaw increases in energy prices.

Participants

This term is used to refer to the members of staff who received training and participated in the integrated implementation which was the situation for the action research. The participants were drawn mostly from the shopfloor workforce but also included one member of the office staff – more were included in a subsequent training session. The shopfloor participants represented all levels of seniority and also included a representative from manufacturing support (toolroom). Participants mentioned directly were:

- Participant 1 – the representative from manufacturing support.
- Participant 2 - an assembly team leader. Her area was the focus for a 5S exercise which included red tagging, which is mentioned later in this chapter.

External Lean trainers

Two trainers from an external Lean training provider presented the training and guided some activities to initiate this implementation. The training provider had a variety of standard training material and activities that could be selected according to the aims and needs of the company. Both trainers had been working as trainers for several years and had gained experience of implementing Lean in various manufacturing environments.

7.3 Action research structure

The structure developed for the first case study was used as the basis for the second case study, and this is show in Figure 7.1. Figure 7.2 shows how the events fitted into the planned stages, plus the main information flows between stages, to explain the actual sequence of events and how each stage was fulfilled.

As can be seen from these diagrams the intervention consisted of a series of meetings, training sessions and guided activities. All the meetings were digitally voice-recorded and quotes were transcribed where they made points which related to the research aims of the meeting, added a new thought that was pertinent to the research aims, or corroborated (or disagreed with) a previous finding or thought. During the training sessions notes were taken of significant events, data, comments or reactions of the participants and trainers. Sections 7.4 – 7.6 presents this data, and the findings drawn from it, for each segment of the intervention.

7.3.1 Key differences in implementation between Company B and Company H

Differences between the implementations were likely to occur in the case study stage of the research, for the pragmatic reason that companies had to be free to carry out the implementation as they wished. Such differences are in fact not problematic but can help the research by providing the opportunity to observe companies' differing reactions to the proposal, to look for any effects of these differences and compare and contrast the implementations.

It was noted in case 1 that the practicalities of integration with existing training material meant the "environmental" additions could only be made as a discrete training session within the Lean training programme, rather than being included throughout the existing sessions. The external trainers used by company H were happy for the additions to be integrated throughout their training, and for the same trainers who presented the rest of the training programme to present the additions.

Company H decided to add environmental impacts as a ninth waste, whereas company B chose to highlight the environmental elements within the existing wastes.

During the first case study, the researcher acted predominantly as a silent observer but chose during this case study to participate alongside the trainers in discussing wastes with participants, including the discussion of environmental wastes where appropriate.

7.3.2 Bias Avoidance

Section 3.7 (Methodology chapter) presented techniques for avoidance of bias that will be used at various stages in the research. The bias avoidance methods to be used will be the same as those in the first case study – namely, prolonged involvement, peer debriefing, member checking, negative case analysis, maintenance of an audit trail, "Thick" descriptions, sources are identifiable to the researcher, generic processes and outcomes described in conclusions - as set out in section 6.3.1.

7.4 Planning stage

7.4.1 Initial discussion

Aims

The practical aim of these meetings was to introduce and explain the project, its principles and aims, and the proposed form of the case study, in order to allow the company's representatives to decide whether they wished to take part.

The research aims were to discover –

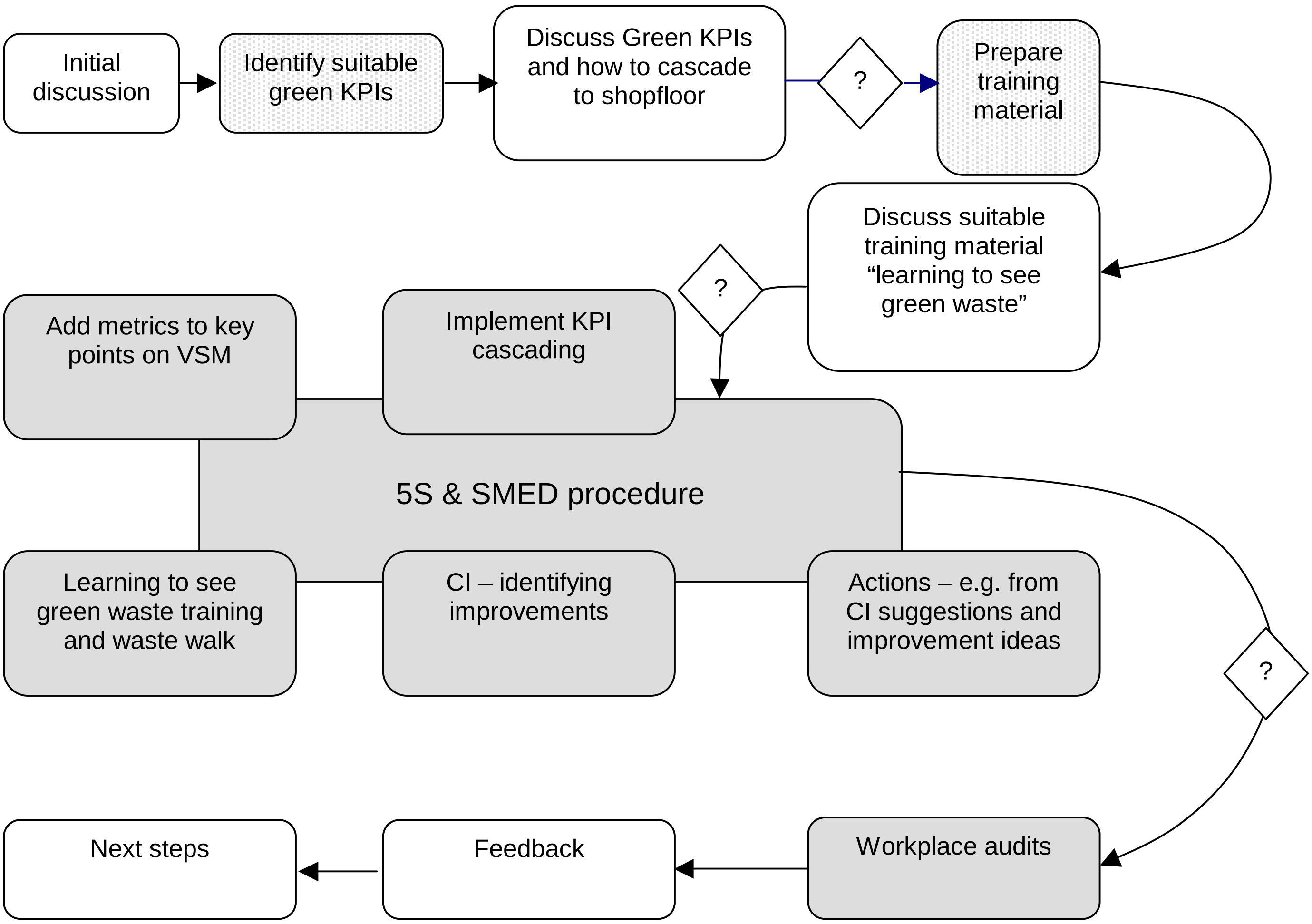
- What made the company accept this proposal? What did they like or dislike about it?
- How well did they understand the ideas, and what helped or hindered their understanding?

Procedure

Initial discussion meetings were held first with the Managing Director (MD), who was known from the interview phase and acted as a "gatekeeper", and then when he had expressed interest, with the MD and the other company representatives he nominated whose agreement had to be gained in order for the case study to proceed. These were the Operations Manager (OM) and previous Managing Director (PMD) (who at this point was still the Managing Director, but for consistency will be called PMD throughout).

These meetings began with a presentation to explain the background to the project and its aims, and to present an outline plan of the proposed intervention. The first meeting lasted approximately half an hour and the

Figure 7.1 – Diagram of structure of implementation



Key

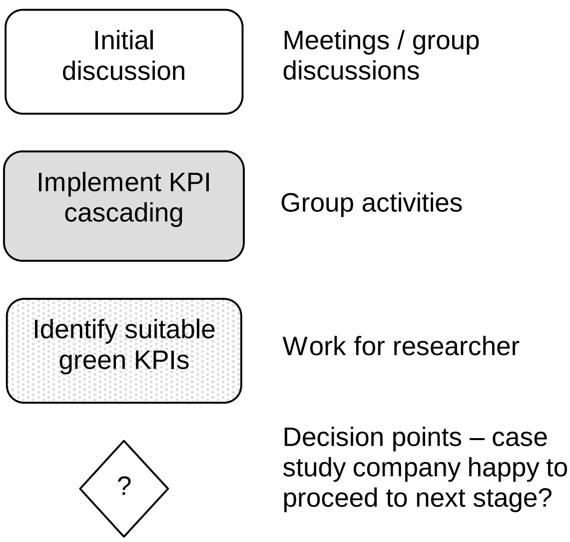
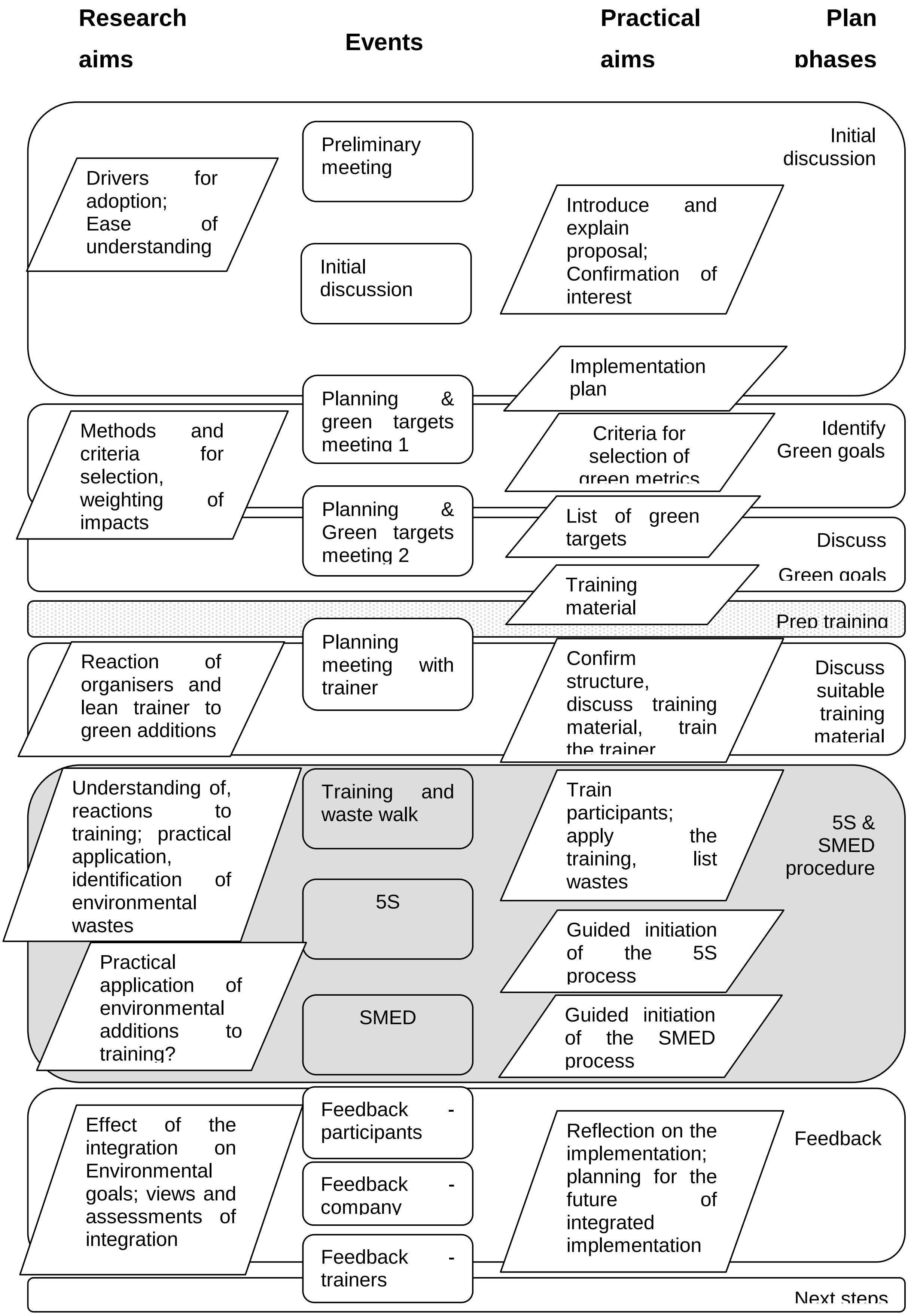


Figure 7.2 – Diagram comparing events with plan phases in case study 2



second nearly an hour. After the second preliminary meeting there was a tour of the factory.

Observations and findings

Value stream thinking in environmental impact reduction and Lean

> *"Lean isn't just concerned with these four walls, it's the entire value stream – so in theory the same kind of thing applies – we're going to get our bit right and then work up the supply chain and work down with our customers and their supply chain, to consider the Lean value stream. The same ought to apply for that example about carbon footprint but also the sustainable stuff - if we're perfect at not doing anything bad here because we've made our suppliers do something that is bad, then it's not sustainable"*

[MD. Prelim meeting 1, 8m20]

Here the MD was expressing doubts about confining the implementation within the boundaries of the factory, and it is true that it would be possible for the less scrupulous company to simply reduce their environmental impact or equally their costs by offloading the polluting or expensive activities elsewhere in the supply chain. Ultimately, just as a Lean company considers the whole supply chain to get maximum benefit from Lean, and an LCA considers the whole product lifecycle to ensure that all the impacts of a product are considered, **a company implementing "environmental impact reduction and Lean" should involve the whole supply chain** [I7-1].

"Environmental* muda *spectacles"

> *"I guess we need to decide what our measures are, and put on our green muda glasses – and then at the decision point we decide whether we want to keep them on or go like that"* (mimes removal of *muda* glasses)

[MD, prelim meeting 2, 44m]

This was the MD's summing up of the first steps of the implementation, towards the end of the meeting.

The statement suggests that the staged approach to agreeing to this project was comforting to the company and may have been instrumental in their acceptance of it – if they made a start and after beginning to understand the ideas better decided it was not something they wished to pursue, they could abandon the project after a fairly small commitment of time and effort.

This statement also indicates that the MD has identified another synergy between Lean and environmental improvement; **learning to see wasteful environmental impacts in activities that have been accepted as normal is a transition, just as learning to see Lean wastes is** [I7-2]. He is applying standard Lean terminology (the *muda* spectacles) to environmental impacts.

Terminology

> *"I'm just sort of struggling with the terminology at the moment because normally if you say something is a green something, then normally that's deemed to be a good thing isn't it? In terms of environment and so on. And then I was thinking that maybe you are just trying to identify wasteful things relating to the environment."*

[PMD, prelim mtg 2, 24m]

This quote shows that **the labels that are chosen to identify tools can affect ease of understanding** [I7-3] and therefore must be chosen quite carefully; there were also differences in choice of labels and the reactions to particular words between companies B and H, indicating that **different companies might find different labels work better even if the concept is the same** [I7-4]. In particular the language around environmental issues can arouse any of a whole range of emotions depending on the personal views and experience of the individual. Then there is the issue of "jargon" which is not popular with this company (and the interview phase showed that this view was shared by others).

Integration of environmental impact reduction and Lean

> *PMD - "One difficulty for me about it is that it's almost hard to separate this from general waste reduction and Lean practice – they're almost the same, aren't they?"*
>
> *MD - "I think that's almost the benefit of it, that it's not separate, I think that's the aim of the project isn't it? That Lean is – forget all the buzzwords and the clever tools and stuff that people do and put labels on it and make nice shiny graphs – forget all that, Lean is about doing the right things and not doing the wrong things, muda, seven wastes, call it what you want, it's about doing*

> *sensible stuff and not unsensible stuff, and if that sensible stuff happens to save the planet too, then it would seem almost by default to be quite a sensible thing to do. And therefore it's all part of the same thing, it's all part of doing the right thing, rather than spending our money doing the wrong thing. And so I think it's quite an interesting angle, because it's not different."*
>
> [PMD & MD, Prelim mtg 2, 27 m 15]

This conversation shows that **the environmental additions suggested are a good fit with Lean** [I7-5] – the PMD thinks they're *"almost the same"* implying that the two ideas merged effectively for him and the MD replied that they are *"all part of the same thing".*

The MD commented during the interviews on his dislike for "jargon"; for him the key to Lean is "doing the right thing" so by including the environmental improvement actions as "all part of doing the right thing" he is giving them significant weighting.

Acceptance

The decision to proceed up to the first decision point was swift and unanimous. The staged approach seemed to help. The MD commented that they could try out the first stage and then had the option to cease integrated implementation if they wished [MD, prelim meeting 2, 44m].

The timing of this proposal was fortuitous as the company intended to commence 5S training imminently. One of the proposed tools mentioned in the presentation was "environmental" 5S and so this probably helped to emphasise the way the two projects could work together [MD, prelim meeting 2, 46m].

The main attraction of the project seemed to be that producing waste of any kind does not make sense to this group. The MD's "doing the right and sensible things" mantra seems deeply embedded. Although they are not all very experienced in Lean thinking, they do want to take all possible steps to avoid waste, and this project seemed to appeal by defining another sort of waste which could be reduced without too much extra effort [PMD & MD, Prelim 2, 27 m 15]. Company H already had a history of making efforts to reduce environmental impacts that are also expensive (the PMD discussed the energy saving measures and renewable energy schemes they wanted to include in the specification of their new building, but this was predominantly because they foresaw rising energy prices [PMD, Prelim meeting 2, 36m]), so this aspect of the concept appealed to them. This exchange between the PMD and MD also implies that the integrated implementation was actually easy to accept as it did not appear to be a change on a very large scale.

Overall, **the idea of integration was acceptable** [I7-6].

Understanding

The PMD indicated one way in which understanding was hindered (he found the terminology troublesome) but also that the integration of the concepts was easily understood (because he could not see the difference between standard Lean and Lean with the environmental additions).

The quotes from the MD at this stage show that he was reiterating some of the ideas that had been presented in his own words and generating some new links, which indicates that he had understood the ideas and found them interesting. He had the greatest understanding of Lean and so perhaps it is not surprising that he found it easiest to grasp the additions to it. He found and discussed more parallels between Lean and environmental impact reduction than the researcher had suggested at this stage – for example, the need for environmental improvements to consider effects throughout the value stream and the need to learn to see wastes (see above).

Generally, the organisers present at this meeting seemed to find that **it was easy to understand the proposed integration of Lean and environmental improvement** [I7-7].

7.4.2 Identify environmental goals

Aims

The practical aims for this section were to choose categories of environmental impact to target during the implementation. The brief was to select categories that were among the company's largest environmental impacts, without spending a lot of time working out exactly which were the largest – beyond this the criteria for choice were open for discussion.

The research aims were to find out –

- What method and criteria do the company use for selecting goals and why?
- How do they weight cost, operational and environmental impacts?

Procedure

In the first case study the researcher generated a shortlist of possible impacts to target based on company B's Environmental Impacts and Aspects Register. Company H had no similar document so an alternative approach was developed. A meeting was held between the MD, OM and researcher to discuss the environmental impacts of all the company's activities. Their list of cost codes was used as a basis for the discussion as it forms a complete list of their activities.

These meetings also allowed more detailed discussion of the procedure and schedule for the implementation.

Observations and findings

"One holistic thing"

> *"We're going to use the (external trainer) thing, 5S, to involve everybody - a formal 5S program. So if we stick on a sixth S, for sustainability, we could wrap these things into that – do you think? So rather than having a number of different things going on in different places we could have one holistic thing"*
>
> [MD, goals mtg 2, 1m 30]

> *"They fit in quite well – a lot of this stuff... in a lot of ways if you're running the training for people in 5S then you're running this on the back of it or all together somehow."*
>
> [OM, goals mtg 2, 5m]

These quotes show that the MD and the OM could see how the training fitted together, and back up finding I7-5 (**The environmental additions suggested are a good fit with Lean**). The MD is also acknowledging that **there is a benefit in reducing the number of different programs running** [I7-8]. (Note that the idea of adding a sixth S was ultimately discarded in favour of adding a ninth waste).

Goal setting

> *"we could get all picky and introduce all sorts of sub-measures, but ultimately it's about pounds. So we could scratch out a few examples and do some calculations that say that was that much*

> *– but the key thing ultimately is how much we give to the electricity company at the end of each month"*

[MD, goals mtg 2, 14m30]

> *"because they're high level and less granular, there is that tendency that they're going to be divorced from activities, which is then that key bit of the awareness – so there's some high level graph and it's only got a thousand pounds on it, so how does me turning off the lights affect that unless we separate it out and measure the lighting circuits? So you get less detail, less granularity, by considering the high level one which kind of divorces it from activities – but really life's too short, so if we get the right level of awareness, we can say that fifty people switching off a light for an hour is that many pounds – so although you're not going to see your penny on the graph, that's how much it saves when you do it, so do it – so that's the importance of the awareness, introducing the topic quite broadly then becoming quite specific to say me as just one person can have this impact by doing this and our overall measure if we do all these things and add them all together will come down."*

[MD, goals mtg 2, 17m]

While at company B there was a strong emphasis throughout the implementation on the use of measures to drive behaviour, at company H it could be observed that there was an emerging emphasis on educating the workforce and changing mindsets.

The MD at company B wanted to provide straightforward top-level goals, with one goal that applies to all levels within the workforce rather than a "cascaded" series of goals; and he preferred to use simple, plant-level measures of progress towards the goals which are directly related to cost and usage, rather than spending time and money to make very precise measurements of effects of changes. He feels that the cost of the time taken to set cascaded goals or set up measures with greater granularity would not provide enough value to be worthwhile. He suggests that instead of using measures to allow participants to understand what difference they are making, this can be achieved by education – they must put more effort into educating their workforce so that they have higher levels of understanding of what efforts are required and what effect their efforts will have on the goals (for example by providing lists of desired actions and the effect they would have). In summary, **examples of effects and education of the workforce can be used instead of very high-granularity measures and cascaded goals to drive behaviour change and link top-level goals to everyday actions** [I7-9].

This is a pragmatic approach to the issue of the cost of measuring, but it is not perfect, as some actions may have unexpected effects on environmental impacts (either for better or for worse) and this approach means the company cannot learn from them; also care would have to be taken to ensure that the participants understand that this is a list of examples and there is scope for them to suggest other improvements.

Environmental value stream mapping

> *"I think it would be interesting if you did a green value stream – even if you did the current state, just did that, that would be interesting – if we did the future state and started to add some things to it..."*
>
> [MD, goals mtg 2, 20m15]

This statement was interesting because the organisers showed interest in the concept but did not carry it out. This may have been an issue of timing. The elements that were selected were those that fitted in easily with the elements of Lean that were being used so the environmental elements were thoroughly integrated and were not a lot of extra work. The company had not already done a mapping exercise so it is much more likely, and more sensible, that they will carry out a value stream mapping exercise when it suits them to do so, and perhaps would then integrate environmental elements.

There is potential for the addition of environmental impacts to value stream maps to be useful, but environmental value stream mapping makes most sense as an addition to an existing map or when one is being created [I7-10]

Goal selection

It was decided that **goals must have a financial benefit as well as an environmental one** [I7-11], and that **the goals must be things that the participants they were selected for could act upon within the normal scope of their role** [I7-12] although company H were happy to have top-level goals that applied to everyone and educate employees on the cumulative effect of small changes they could make towards these goals (see I7-9 examples of effects and education of the workforce can be used instead of very high-granularity measures and cascaded goals to drive behaviour change and link top-level goals to everyday actions). It was also necessary that **goals selected should be suited to incremental continuous improvements rather than one off step changes** [I7-13]. The discussion of impact classes that were felt to be more suited to one-off improvements generated some interesting project ideas that were noted and may be carried out at a later date. This was an unexpected benefit, gained simply from having the organisers discuss all the company's activities and consider the related impacts and costs.

The goals finally selected were:

- Cardboard (this included the packaging on goods inwards and goods outwards). They have a system in place to bale up and sell all their waste cardboard, but this is a wasteful process in Lean terms. Feedback from their customers suggests that they do not like cardboard packaging as they have to dispose of it.
  Environmentally, the main issues with cardboard include the processing and transport energy throughout the lifecycle and the impact of any bleaching process. Packaging on goods outwards might not be reused or recycled, creating end of life impacts (and the recycling process has its own impacts).
- Energy. Electricity bills are a major cost for the company.
  Environmentally, energy generation is associated with emissions of carbon dioxide, which is believed to cause climate change, and of particulates, mercury, and other pollutants – also the burning of fossil fuels which are finite resources.
- Compressed air. This is really a subset of energy use as it was chosen because its production is energy intensive – however it was felt to be worthwhile selecting this as a goal because it is one of the main uses of energy within the plant, and there is plenty of scope for the shopfloor workforce to make suggestions to reduce the amount used.
- The number of CI suggestions made that will reduce environmental impacts.
- Pages printed. The printers at the company are paid for by number of pages printed so there is a direct correlation between pages printed and costs. Environmentally, each page printed is associated with the

lifecycle impacts of the consumables (paper and ink) and the electricity used to run the printer.

Other possibilities were discussed but discarded –

- Transport issues (of people, commuting or travelling on company business, or parts). There is currently a project looking at arranging more local supply of parts, but there are only a few people in the company that can have much influence on this and it is likely to be a one-off step change project – the company felt that goals ought to be more amenable to continuous improvement.

  Commuting travel is more influenced by this company than many others as they organise transport by bus for people living near their old works.
- Water use

  The company's water use is not that large and the cost is several times smaller than the cost of the electricity used.
- Material use

  The company had already made considerable efforts to reduce their material consumption (for example by rationalising the arrangement of components for stamping) so it was felt that the opportunities for further reductions would not be that great.

Weighting cost, operational and environmental impacts

There was no formal weighting attributed, but **the goals had to have the potential to affect both environmental and financial or operational impacts** [I7-14] – weightings are attributed informally by an estimate of total impact – so goals could be selected if they had a high financial impact, provided there was some potential for environmental improvement, or a high environmental impact, so long as there was some associated cost.

7.4.3 Training material – preparation and discussion.

Aims

The aim of the "environmental" additions to the training material was to explain the concept of "environmental waste" and what the environmental goals are, why they are important and what people are expected to do about it. The researcher and the company organisers were in agreement that these additions needed to fit in seamlessly with other training materials, and be distributed throughout the material, because it was hoped that they would be accepted as one of the normal aspects of Lean rather than an addition. The standard training material defined Lean's eight wastes, and **the company had decided that they would integrate environmental waste as a ninth waste** [I7-15]. Finally the additions needed to be made memorable in some way.

The main practical aim of the meeting to discuss these additions to the training material was to check that the company and external training organisation's trainers were happy that the training would effectively convey the required message, and that the trainer understood the project and the training material. This was also a chance to confirm with him the structure of the implementation and have a general discussion of the practicalities.

The research aims for the discussion meeting were to –

- Find out how a Lean trainer reacts to the integration of environmental impact reduction and Lean – does it make sense to him and is he enthusiastic about this? Is he happy about integrating this message throughout the training?
- Find out what the trainers and company organisers liked or disliked about the modifications to the training material

Procedure

The slides that were normally used in the training were obtained and examined by the researcher, in order to understand the structure and style used and to assess where and how the environmental additions might be integrated throughout the material. The researcher then integrated the "Environmental" element into the training by adding dedicated slides explaining firstly the concept of environmental waste, then the environmental goals and why it is important to reduce these environmental impacts; and by integrating the environmental message into other slides dealing with general discussion of the Lean principles, for example as another point in a list of the effects of Lean. The external training company own copyright to the slides so they are not shown.

The discussion of the additions took the form of a meeting with the MD and external training organisation's trainer. Each proposed addition to the slides was presented and the researcher checked at each stage that the trainer was comfortable with the addition and how to present it and understood the underlying principles, and that the MD and the trainer both agreed that this addition should be included. The form the intervention would take was finalised at this meeting.

Observations and findings

> *" in the original sort, can we replace compressed air with a cheaper source of energy, maybe from a free air blower, there may be other ways of doing it – or are we using compressed air in the most effective way. Can we amplify it using particular nozzles, or whatever. There are things you could actually talk about around those green issues."*

[external trainer 1, training material discussion, 12m15]

Here the external trainer suggested that **additions could be made to the regular audit checklists to include environmental improvements in best practice** [I7-16] – the audit checklists are used to ensure that once best practice is agreed it is being followed and that improvements are maintained rather than standards being allowed to slip – for example, leaving lights on or leaking airlines could be items to check for on the audit.

He also thinks that **there is scope for considering environmental improvement within 5S** [I7-17]. The improvements here are on different levels – in the auditing suggestion, the points to audit are quite simple best practice whereas the "Sort" environmental activity proposed is looking for a rethinking of the whole way of doing things. Both draw on fundamental ideas in Lean, of formalising best practice and trying to rationalise procedures and challenge the established way of doing things if it is or might be wasteful. The external trainer is demonstrating that **integration with Lean encourages companies to question the fundamentals of their manufacturing methods for environmental and financial benefit** [I7-18]

The fact that he is generating new ways to fit environmental improvement into Lean suggests that he has understood the ideas and is engaging with them, as well as the idea being interesting in itself.

Reactions to the training material

The company representatives and the trainer were happy with the training material and did not have any requirements for changes.

The trainer said he could see the sense in the integration of environmental impact reduction with Lean. The trainer was happy to present this training and understood enough about the environmental aspects to do so. It was felt that on a practical level this would help the training to appear seamless and holistic, whereas if the researcher had presented the environmental training, as in the first case study, this gave the suggestion that it was an addition – and on a research level, it would be interesting to see how a Lean professional dealt with this addition to the training. He felt the distribution of the "environmental" message throughout his training material was appropriate.

The company representatives were happy that the "environmental" elements were well integrated into the material, as they had agreed that this should not appear to be a separate "add-on".

7.5 Activities

7.5.1 Training and waste walk

Aims

The practical aims of the training were predominantly to provide this group of participants, who were new to Lean, with enough knowledge and understanding of the principles of Lean for them to be able to begin to make improvements and work in "Leaner" ways. As previously explained the environmental additions to the training were intended to explain the concept of "environmental waste" and the environmental goals that had been selected, why they were important and what participants might do about them.

The research aims for the training were to observe the participants' reaction to the training (in particular the environmental elements and additions), and to see how the trainers dealt with this addition to their usual program.

The aims of the waste walk were to help the participants to apply the theoretical training they had received to their own workplace, and in doing so to understand it better; and to generate a list of wasteful activities that would form the basis for later stages of the training and could be acted on as the implementation progressed. This applied to environmental training and wastes as much as the standard Lean ones.

The research aims of the waste walk were to -

- Find out whether the participants managed to apply the training in practice and

- Find out whether the participants were able to identify environmentally wasteful practices.

Procedure

The environmental training was presented by the same trainer as the rest of the training, by inclusion of environmental aspects in the normal Lean training material, as discussed in section 7.4.3. The researcher was present during the training sessions and was introduced by explaining that she was investigating the environmental effects of implementing Lean. The sessions were not recorded but the researcher took notes of any points of interest, such as number and nature of suggestions for reduction of environmental wastes (and total number of suggestions, for comparison), reactions to trainers' questions, reactions to training, and the trainers' approach to the modified training.

The waste walk took place before the participants had been trained on the types of waste, but after they had been given a description of what waste means, in Lean terms, and what environmental waste means. They were then instructed to go out into the work area and write down on sticky notes the wasteful activities they could identify. The trainers and OM and the researcher were available to discuss wastes and to help any participants who were struggling to identify any wastes, although this proved not to be necessary with this group.

Observations and findings

Participants' reaction to the training (in particular the environmental elements and additions)

When participants were asked by the trainer to recall the types of waste at the beginning of the second day's training, the first two participants to respond both said environmental waste.

How the trainers dealt with this addition to their usual program

This was the first time the trainer had presented this modified material. For the most part he seemed able to explain the new points easily, and they seemed to fit seamlessly into the rest of the material. So **environmental additions can be integrated smoothly into existing Lean training material** [I7-19]. He used additional environmental points on occasion when making his own additional explanations and examples unprompted by the training material, showing that **an experienced Lean trainer can ad-lib environmental additions to the training in addition to his own Lean points** [I7-20].

Practical application of the training by the participants

During the waste walk the researcher spoke to most of the participants. All were able to identify some form of environmental waste although this was mostly restricted to things like leaving on lights or computers. Several participants did start to discuss some less obvious impacts such as whether leak detection sprays contained CFCs (which had not been discussed in the training and would be an environmental impact although it was not one that the company had chosen as a goal) without prompting from the researcher. This shows that **the participants were able to identify environmentally wasteful activities and apply the training in practice to some extent** [I7-21] but also that **participants seemed mostly to be focussing on fairly simple "overhead" type impacts** [I7-22] (e.g. lights and computers) rather than those involved in manufacturing and assembly processes.

Identification of environmentally wasteful practices

During the waste walk 49 wasteful activities or practices were identified and once the walk was finished, the participants reconvened to rank the wastes identified. Each waste was ranked high, medium or low for their frequency of occurrence and impact on the business, with the participants discussing each one until they reached a consensus of opinion. Figure 7.3 shows the environmental wastes and the frequency and impact ratings they were assigned.

Ten of the wastes that were ranked high for frequency and severity were then selected as the "top ten" wastes, and each participant selected their "top five" in order of severity. "Leaving on lights and PCs" and "compressed air leaks" were in this top ten and by cumulative scores were ranked joint ninth and seventh out of the top ten, respectively – so **participants think the environmental wastes are important** [I7-23].

This exercise also showed that **suggestions for environmental impact reduction can be integrated into Lean suggestion schemes** [I7-24].

Figure 7.3 – Table of environmental wastes identified (company H)

Waste description	Frequency of occurrence	Scale of impact (on business)
Lights left on on benches when not in use	High	High
Over-packaging of parts from china	Medium	High
Packaging on defective parts		
Monitors / PCs left on when not in use	High	Med
Compressed air leaks	High	High
Rubbish on the shopfloor (this was attributed as an environmental waste but this classification is dubious)	High	High

7.5.2 5S activities

Aims

The aims of this activity were to give the participants a guided “kick-start” into putting the 5S theory into action, in a given area, so that they would know how to proceed to implement it in the rest of the work area.

The research aims were to –

- observe the 5S process and see whether the participants appeared to be reacting to the environmental additions to the training they had received.

Procedure

During the period when the trainers were at the company, the first three “S’s” (sort – make sure only the relevant items are in the area, set in order – put everything in a sensible place and mark this location, and shine and sweep – clean up the area; eventually a regular cleaning schedule should be agreed but this session focussed on an initial cleaning and tidying to raise the standard) were begun in one area.

Again the researcher recorded notes rather than voice recording for this event, because background noise from the factory meant voice recording was not a viable technique.

The area was marked out and everything was removed and sorted – either set on one side for replacing, thrown away, taken to a more appropriate location or, if there was some uncertainty about whether it was wanted or not, or some action needed to be generated with respect to it, it was "red tagged". The items to be replaced were cleaned and put back in a set and rational location and the location was marked. During this activity some on-the-spot improvements to practices were made, and some items that were required for better efficiency were procured or noted – these were often very small and simple.

Observations and findings

During this phase the participants appeared to be completely focussed on the practicalities of improving process efficiency and no mention was observed of reducing environmental impacts.

It was observed that this exercise was effective both at making a physical change in the work area and initiating a change in the participants, in understanding and enthusiasm. Once assembled in the work area they appeared at first to be rather nervous of getting started but as the trainer gave people specific tasks and started moving benches himself their confidence grew and they worked with increasing enthusiasm and took on new tasks of their own volition. At the end of the exercise, which only lasted around two hours, the work area was visibly different to both its former state and the areas around it and the participants were visibly more confident and enthusiastic, and were impressed with what they had achieved. The changes made included some simple but effective changes to processes and requests for new storage hardware as well as the standard cleaning, tidying, marking locations, relocating or disposing of irrelevant items that the participants had been asked to complete. Harnessing some of the power of this technique might facilitate more environmental improvements by allowing better practical understanding and confidence, providing a dedicated time to make changes, and giving participants experience of making changes.

It was clearly demonstrated that practical exercises where participants can be encouraged to try out the Lean techniques and see how they work in their own environment, with guidance and encouragement from the trainer, are very effective and **it would be beneficial to include an environmental element in a practical training exercise** [I7-25]

7.5.3 SMED

Aims

The practical aims of the SMED exercise were to reduce the time taken to change tooling and set up for the manufacture of a different product type when changing from one to another.

The research aims again were to –

- see whether participants, organisers or trainers were bringing anything from the environmental impact training they had received to this part of the implementation.

SMED Procedure

The foundation for the SMED analysis was a video of a tool change. This allowed the participants to break down the tool change into individual activities, including the wasteful ones such as walking around looking for tools, waiting for a supervisor or another process etc. This was a useful technique as it allowed classroom analysis and discussion of a shopfloor activity and examining each action in the classroom seemed to help participants see their normal activities with new eyes, as well as allowing pauses for discussion and rewinding.

As the video ran the time taken for each activity was noted and ultimately the actions and times were assembled into a gantt chart. Each activity was coloured according to whether it was internal (had to be done while the machine was stopped) or external (could be done away from the machine while it was running) and value adding or wasteful. The chart allowed participants to create an improved future state process, where activities that could be done externally were done in parallel with the machine's cycle, wasteful activities could be removed, and the longest useful internal activities targeted for improvement.

Observations & Findings

At the end of this exercise some suggestions were made for changes that could be made now and for no or very little cost (for example, installing tool boards, rationalising the layout of the work area, and creating a rationalised procedure for changeovers) and some suggestions that would require a more complex, longer term project with investigative work and capital expenditure approval (for example modifications to tool design). It was estimated that these could make very considerable reductions in setup time, which could increase overall parts per unit time production rates, and/or allow shorter production runs of a given part type if required (which is often useful in line with Lean principles).

During the discussion at the end of the exercise the trainer instigated a discussion about the environmental effects it had had. It was suggested that if all the suggested modifications were implemented, a considerably raw material saving would result and participants could see the savings that would result all the way down the value stream for the raw material production and supply. They could also see that there would be a reduction in "overhead" impacts such as heating, lighting, power to the production machinery etc.

It was not clear that the environmental training had caused the trainers or participants to do anything differently during the SMED implementation, so there was no change in the environmental impact reduction that resulted – unless the training helped them to be aware of the raw material reduction and this is used to help make the case for capital expenditure approval for the tool modifications etc. but the fact that the discussion was initiated showed that **trainers and participants were giving consideration to environmental impacts without prompting** [I7-26] and that **there are environmental improvement side-effects from a standard Lean implementation** [I7-27]; additionally, that **there is potential for SMED to reduce environmental impacts** [I7-28].

7.6 Results, feedback & next steps

7.6.1 Aims

The practical aim of these meetings was to provide a chance to reflect on how the implementation went and what was achieved. For the company organisers this was also a chance to discuss whether they would continue to implement the "environmental" additions to Lean, and if so, in what form.

The research aims were to investigate -

- What they felt were the links, similarities, synergies between environmental impact reduction and Lean after the combined implementation
- how the implementation affected the environmental goals / other environmental impacts
  - o which of the actions for improvement proposed during the integrated implementation trial have been implemented and whether there are others that they plan to implement in future
  - o what else they have done as a result of the integrated implementation trial to reduce their impacts
- whether they will continue to integrate "environmental impact reduction and Lean" – what they will change, continue, stop.
- what they felt worked well, and what did not work so well
- how they felt the participants reacted and changed
- whether the trainers felt, after time to consider the implementation process, that this method might be applicable in other settings

And to gather general comments and impressions on the implementation, and what effect linking environmental impact reduction and Lean has.

7.6.2 Procedure

Feedback was sought from three groups of people in three different meetings. First there was a feedback session towards the end of the case study for the participants, which was around a month after the initial training session with the "environmental" additions. Second the external trainers were asked for their feedback, and third was a meeting to discuss the implementation with the company's organisers (the MD and OM), approximately two weeks after the second part of the training / guided implementation. All of these feedback sessions were semi-structured; prior to the meeting the researcher drew up a list of key questions (listed below), but there was also time for general discussion and to follow up any other points of interest raised.

Discussing the future of the implementation and ideas for future activities was part of the Feedback meeting with the company organisers. Also at this meeting (and during observation of the implementation) certain more quantitative data was gathered, in order to assess the planned and actual effects of the implementation on the environmental goals and other environmental impacts.

Participants' questions

- Can you remember what the environmental wastes are?
- How important do you think it is to act on these issues?
- How important did you think it was before undertaking the training?
- Did you do anything differently as a result of the training?
- Have you been looking for changes to make to reduce environmental impacts?
- What do you think has changed in what company H expects of you now that you have been trained?
- Can you see how these issues tie in with Lean?
- Does including these issues with Lean make it easier to understand the issues and do something about them?
- Have you got any more environmental suggestions to put forward now? (If so, why haven't these been put forward before?)

Trainers' feedback

At the end of the implementation the trainers were asked for their views on the integrated implementation, the experience of presenting the training material prepared, and their views on its applicability to other companies.

Company organisers' feedback

The organisers' feedback meeting began with a presentation in which the researcher summarised her observations of environmental improvement actions, suggestions and project proposals generated during the case study, presented some suggestions for future implementation, and then gave some preliminary research findings. Organisers were then asked to comment on each of the points raised and to add their own observations under each category, and also about how their views might have changed, if there was anything that surprised them, and any views on links or inhibitions relating to integration of environmental improvement with Lean.

7.6.3 Findings

Effect of the implementation on the environmental goals / other environmental impacts

The main changes the company reported that were made to reduce environmental impact as a result of the implementation were -

- PCs, lights, fans etc. were more likely to be turned off when not in use
- There was probably a small reduction in defects
- There was a reduction in material purchases
- The SMED exercise identified the potential for significant material savings, but requires justification and approval for capital expenditure.

The effect of the implementation on the goals and on other environmental impacts is discussed further, below.

Goal 2 – Reductions in electricity usage

> Researcher - *"there's the whole thing about pcs getting turned off, which is – well certainly in the offices, it's not exactly part of the Lean thing is it?"*
>
> MD – *"Not necessarily, but it did come out of the training and people thinking a bit more and saying to each other why don't we switch them off."*

[Researcher and MD,company organisers' feedback session, 3m45]

The quotations relate to a screensaver message which was added to all the company's computers asking users to turn the computer off at the end of the day – this was instigated as a response to issues with the limited availability of licenses to use certain software but had also been suggested for environmental reasons by the participants in the Lean program.

Turning off any fans that are still running is now part of the procedure for the managers' evening walk around prior to shutting up the premises for the night, and this came about due to early discussions that were part of the integrated implementation – supporting finding I7-16 (**additions could be made to the regular audit checklists to include environmental improvements in best practice**). Other reductions in energy usage due to the implementation were also mostly of the "switch off and save" type, supporting finding I7-22 (**Participants seemed mostly to be focusing on fairly simple "overhead" type impacts**). Managers felt that this was not a key part of the Lean implementation; but they also felt that **there was an increase in awareness and a change in mindset brought about by the training** [I7-29], and that staff were in general more aware of switching off lights and fans etc. when they were not performing any useful function.

Goal 1 – Reductions in cardboard (goods in and goods out) & goal 3 – Reductions in compressed air demand

No improvements were reported in these.

Goal 4 – "Environmental" suggestions made

During the waste walk six wasteful activities or practices were placed in the environmental impact waste category, out of a total of 49 identified for all waste categories. Of these two were ranked in the "top ten" most important and highest impact wasteful activities and practices. This is discussed in more detail in section 7.5.1 , where findings I7-21 (**The participants were able to identify environmentally wasteful activities and apply the training in practice to some extent**), I7-22 (**Participants seemed mostly to be focussing on fairly simple "overhead" type impacts**) and I7-23 (**Participants think the environmental wastes are important**) were recorded in relation to identification of environmentally wasteful activities.

At the point when the feedback meetings occurred, no other environmental suggestions had been recorded. The company had just started a suggestion box scheme, and was in the process of discussing methods for setting up a formal system for displaying suggestions and posting feedback, actions and progress on them [MD, company organisers' feedback session, 1h 07m].

During their feedback session participants were asked whether they could think of any further ideas for environmental improvements that they had not already suggested. This question generated four suggestions of ways to reduce the environmental wastes and most of the participants began to enter into the lively discussion that ensued (whereas during the rest of the feedback session they had been quite unresponsive).

The first suggestion raised was to reuse packaging from goods inwards in goods out, providing that it was clean and of suitable dimensions. Currently waste cardboard is baled for collection by a recycling company but reusing it would further reduce environmental impact. It was also suggested that using sensors to ensure that lights were only switched on when they were needed (for example in the toilets) might save some power. The suggestion that taps could also be on timers (so that they shut off automatically after a given time) caused some discussion, as some pointed out that if the timers are set too long they could use more water, given that it is fairly unusual in this company for taps to be left on. A further problem identified was that toilet rolls were being left by the sinks for use for hand drying, which was seen as wasteful. This suggestion was quite interesting as participants immediately analysed the root cause (the air hand driers are inefficient).

This shows that **participants can generate environmental improvement suggestions when prompted, and can identify the root cause of problems causing excessive environmental impact** [I7-30].

Goal 5 – Pages printed

This goal was considered more suitable for the office areas. People from these areas have received training but did not for example complete the 5S practical session of clearing an area of their workspace and putting back only what was required and in marked locations. The company organisers acknowledge that more work is required in these areas and no change in this goal was reported.

Side-effects

> *"We're consuming this stuff to throw it away – it's not very clever, is it?"*

[MD, company organisers' feedback, 1h 51]

> OM - *"In general, in terms of having lots of mistakes here and there, it (error rate / scrapping rate) has come down. I'm not sure it's related to this whole thing, but I'm sure it's had an effect on it"*
>
> Participant - *"we're trying to catch it earlier so we're not wasting as much"*

[OM & Participant, Participants' feedback, 14m]

> MD – *"By doing this and reducing the amount of stock we're using, the raw materials we're using, it's much less, so we save quite a bit of orders coming through, like the mild steel and stainless steel – and we're not having so much overtime, and that means that not a lot of electricity, plating, temps in, wasting resources – doing all that, it's all linked, really"*
>
> MD – *"and that's a virtuous circle, isn't it?"*

OM – *“Yes…”*

MD - *“because you’ve got less* (material) *about, so it’s easier to keep it tidier, easier to have the right thing in the right place so you’re less likely to make mistakes, so there’s a reduction in defects that is difficult to attribute directly to it but it’s one of the things that comes out”*

[OM & MD, company organisers’ feedback, 6m]

Both the organisers’ and the participants’ feedback sessions concurred that defect rates and mistakes were probably a little lower, reducing the lifecycle impacts due to wasted components. Both also felt that it was hard to attribute this directly to the Lean implementation – but that the mindset induced by the implementation had again helped to bring about this effect which is beneficial in reducing environmental impacts all the way down the value stream and in reducing financial costs.

During the goal setting stage of the implementation the company had felt that they had already made such inroads into minimising material usage that this should not be chosen as a goal. However, the implementation unexpectedly proved to make material reductions in two main ways.

The company has reduced its stock held in line with the principles of JIT and thus the production manager pointed out that there was a resulting cumulative effect from reduced raw material acquisition, processing and transport impacts etc. all the way down the value stream of the materials, which had been avoided.

Although this was probably a one-off reduction, due to the stock reduction rather than a reduction in the material that goes into each product, the organisers felt that there would also be a reduction in stock wastage due to better practices engendered by the Lean implementation, with respect to identifying and storing stock for example – and these would have similar cumulative effects. They were reaching a point where growth of the business would soon have meant they had to look for more storage space, but reducing stock levels held has postponed this, again reducing the company’s “overhead” environmental impacts.

The SMED project team has identified several ways to reduce set-up times which would also reduce the amount of material wasted while setting up, but as a significant part of the solution would require capital expenditure the project is on hold as yet pending approval of this expenditure.

In all, the OM predicted that after six months or so, about 80% of the material reduction would come from the one off stock reduction, and about 20% from various improvements in efficiency. [OM, company organisers' feedback session, 27m20].

A further unanticipated environmental impact reduction came from the reduction in overhead impact due to more efficient operations reducing the amount of overtime working. Sticking to standard hours means that the factory does not need to be fully lit and heated etc. outside these standard hours.

Summary of findings from progress towards goals

There was some progress towards the chosen environmental goals, but it was limited [I7-31] and some of it was made as a side-effect of the standard Lean procedure rather than being directly attributable to the environmental additions to the implementation; the company would probably have made gained the environmental benefits noted in the "side-effects" section if they had completed a standard Lean implementation. However **because of the environmental additions to the implementation the organisers were more aware of the environmental impact reductions they had made** [I7-32]; they had not considered these benefits before but were able to discuss them in response to this project. This puts them in a better position to seek out environmental improvements in future. Also the OM felt that **environmental improvements had been made through a series of small changes which might add up to significant change but were hard to recall and report** [I7-33]; to assess the effect of all these changes would be very difficult and time-consuming, and they were not sure of the benefit such an exercise would bring [OM, company organisers' feedback, 18m].

These results also support finding I7-27 (**there are environmental improvement side-effects from a standard Lean implementation**).

Views on the links, similarities and synergies between environmental impact reduction and Lean after the combined implementation

Learning to see

> *"I think it's an interesting process to go through because it's very much like when you go from muda unaware to muda aware - you saw the reaction of some of the people round here, it's that light*

coming on bit, where you suddenly think well I probably kind of knew that anyway but never quite thought of it like that"

[MD, company organisers' feedback, 1h 45]

"I would draw then a very strong parallel between that moment of transformation in Lean and that moment of transformation in sustainability"

[MD, company organisers' feedback, 1h 49]

This quotation supports finding I7-2 (**Learning to see wasteful environmental impacts in activities that have been accepted as normal is a transition, just as learning to see Lean wastes is**), but in this case the MD is reporting his observations of the participants and organisers, rather than his own reactions.

Value stream impacts

"We look at SMED, which is straight forward Lean methodology, and one of the key things that we'll see from it will be reduction in scrap, which will be lumps of stainless steel coming out of the factory which will reduce our cost, and it's going to mean that we need to buy less material in the long term which will save us money and save us space – that will be a good thing – cost per part will go down and we'll be throwing less stuff away, less will be going to the scrap place. But you take it back up the value chain and think well, that's less stainless steel going through the rolling mill, less steel going through the convertors to be made into stainless steel – that's a huge drain of electricity – less steel being taken from the iron and coke, that's a huge pollutant"

[MD, company organisers' feedback, 1h 50]

"So if everyone didn't (waste material in set-up) *then the impact back up through the value stream in terms of sustainability, not only for our business but for the planet – it's massive, and so we think about it like that"*

[MD, company organisers' feedback, 1h 59]

The MD commented several times during the company organisers' feedback meeting on the changes in environmental impact throughout the value stream as a result of changes within the factory. It seemed that **Lean encourages the consideration of the effects of changes on the whole value stream**

of a product and this can also be translated to consideration of environmental impact changes throughout the value stream [I7-34].

Holistic integration

> *"*(at the initial discussions about integration) *we focused quite specifically on environmental KPIs, but what developed further downstream was a much more holistic program within which there was a strong recognition of the environmental impacts and benefits of doing the wrong thing. And therefore if we're looking at this holistic thing which has some strong environmental outcomes are the set of KPIs that we were talking about when we were just talking about the environmental impacts of Lean – is it right to separate them out like that?…"*

[MD, company organisers' feedback, 17m]

> *"I think if you're viewing it holistically then you should be on the right track – I think it probably gets – I would say that they would inhibit each other if you viewed them as separate entities"*

[MD, company organisers' feedback, 2h03]

> *"So what it does bring to the party is another criteria to make a balanced decision, with my example of how do you get 500 lux there? – just put bigger bulbs in – well, that would consume more electricity, but it's the easy one. And if you've got a range of criteria that you've got to meet then you've got to think a bit more, you take the thought that little step further and you think well actually, bring them down a bit, maybe, with the same bulbs – or you can bring them down a bit further and put low energy bulbs in them. Because you've taken that extra step of thought, you've achieved the same outcome, with another benefit and another benefit – we've got the light, which is good for the quality, we've reduced the cost because we've used low energy lightbulbs which consume less, and we've achieved sustainability. And so I think by adding that criteria, and if you say those are the criteria we have to meet, would force you to think a bit further and probably take that extra step and achieve something."*

[MD, company organisers' feedback, 2h11]

The importance of holistic consideration of Lean and environmental criteria at the same time as each other was a theme that recurred throughout this meeting. The MD explained that as he saw it, considering Lean and environmental criteria simultaneously provided mutual benefit and better solutions, and gave one theoretical example and one example from the company's history to illustrate this point.

The theoretical example was to do with lighting design. He suggested that if you decided to alter the company's lighting scheme purely with the intention to minimise environmental costs you might either reduce the power of all the lamps or turn them off altogether, causing safety, quality and efficiency problems and thus running counter to Lean principles. If you made the alterations in order purely to maximise Lean benefits, you might specify lights with a higher power rating throughout the factory and most likely would improve safety, efficiency and quality, but use more electricity. The holistic way to reduce power usage (and thus environmental impact) and simultaneously improve safety, efficiency and quality might be to rationalise the lighting scheme, by lighting storage areas at the minimum lux recommended in standards for these areas, and by lowering the light fittings in the inspection and detailed assembly areas and ensuring that they were positioned correctly to illuminate the work areas – which might also mean that you could use lower power lamps but get better lighting overall [MD, company organisers' feedback, 2h04].

The other example he gave was that of the decision taken a few years previously to replace the old trichloroethylene cleaning system. This decision was in part forced on the company by the approaching ban on the sale of the solvent, but it was also something they wanted to deal with to improve working conditions. A more benign cleaning chemistry involved purchase of an expensive piece of plant and the cost per litre was higher than the old solvent cleaner, but by sourcing a system which recovered the cleaning solution and processed it for reuse, far less needed to be purchased meaning that the system paid for itself in a surprisingly short time, as well as reducing environmental benefit and also providing benefits for the workforce, by removing fumes and odours associated with the old system [MD, company organisers' feedback, 2h14].

The MD felt that this was not the obvious solution to the phase-out of trichloroethylene but that integrating the environmental and financial/operational criteria had resulted in a solution that was more favourable in all ways – and that most problems had similar mutually beneficial solutions given enough thought.

The suggestion from the MD was that, although if you considered making changes either for environmental or for Lean reasons, you might take actions to help one that would be detrimental to the other, **if a problem is considered using both Lean and environmental improvement criteria holistically neither would be likely to inhibit the other** [I7-35]; and in fact, Environmental considerations provide another criterion to come to a balanced decision, by forcing the consideration of more options that lead to a better overall solution, with likely greater Lean benefits, that might not have been thought of without the environmental view. In summary: **by simultaneously considering both environmental and Lean impacts of solutions to problems, a solution would be found that was BOTH "greener" AND Leaner than it would have been, had either one of the criteria been considered in isolation** [I7-36]. The simultaneous consideration of both elements was stressed here – the MD felt that it was very important that elements not be allowed to dominate.

There is also an implication that **environmental criteria should simply be treated as part of the range of criteria or goals for the Lean implementation** [I7-37], rather than running separate workshops or designing specific improvement tools (although there may be more benefits from some parts of Lean than others).

Finally, the comment in the first quotation links environmental impact with the wrong thing to do. Back in the interview phase the OM explained that the essence of Lean to him was about doing the right and sensible things and during the implementation he had come to the conclusion that **there is environmental impact inherent in doing the wrong things and conversely, doing the right things means environmental impact is minimized** [I7-38]. This was backed up by several other comments during the interviews, for example -

> *"The right thing is the right thing – it doesn"t matter what category of muda it's in.... those things are useful for getting that shift in thinking but once they're thinking about doing the right things and challenging doing the wrong things, the categories don't matter"*

[MD, company organisers' feedback, 11m]

Standardisation (e.g. turning off fans)

> Researcher *"I know that you said it was part of your procedure now to turn off the fans, and that that is probably as a result of this"*
>
> OM *"yes"*

[Researcher and OM, company organisers' feedback, 4m]

The procedure in question is informal, which is the nature of most procedures within the company, but it is now part of the usual routine of the managers when closing up the factory at night to check that electrical equipment is turned off where necessary, so **it is possible to standardise best practice for environmental impact reduction** [I7-39].

What worked, and what did not work?

A new idea

> *"I'd never thought about it until you came in here and started talking about it"*

[MD, company organisers' feedback, 1h 49]

> *"It's the kind of thing you see in the two owners of the company is a degree of social responsibility… … so yes, we know about all that stuff but it's not until you think about it and go through the process and think well actually yes, it's all linked, and it does turn out into this thing that we talked about in terms of the mechanism for delivering it – it is actually all linked."*

[MD, company organisers' feedback, 1h50]

These comments show that although there was interest in environmental impact reduction and in Lean within the company prior to the case study, they had not previously considered linking the two concepts.

Integration with 5S

> *"I thought that once we'd had the discussion on that incorporation of sustainability within the 5Ss and as we talked about it and how it could work and how it would be transferred to people and how it fitted in, I thought it was an absolute masterstroke of genius because it made so much sense and it worked so well as a thing."*

[MD, Organisers' feedback, 1h31]

The company chose to use an in-depth implementation of 5S to provide the structure of their Lean improvements, and it was found that **environmental improvement criteria could be used holistically alongside the other business criteria as the foci for the 5S implementation** [I7-40] – bearing out finding I7-17 **(There is scope for considering environmental improvement within 5S**).

Empowerment

> *"I thought that once we'd had the discussion on that incorporation of sustainability within the 5Ss and as we talked about it and how it could work and how it would be transferred to people and how it fitted in, I thought it was an absolute masterstroke of genius because it made so much sense and it worked so well as a thing. So I thought that was, having gone through that journey to get to that point where we sat around and talked about what to me sounded like a really good thing, at that point it made sense and it worked, then I expected it to work – I think the thing that was pleasantly unexpected was the degree of enthusiasm and grabbing it that – and maybe that was because I viewed it pessimistically but I thought we'd come up with something good and it could be understood and we could get some benefits out of it and I think what happened was, we'd come up with something good and people jumped on it and it's changed the way we think out there – not so much up here (offices), which is a shame but I think that's part of the next challenge."*

[MD, Organisers' feedback, 1h31]

> MD – *"we'd have a discussion about something that had gone wrong and say how are we going to fix it and what can we do to stop it happening again – but that wouldn't have been coming from out here – it would just be it happened, we fix it and move on. And now they're saying what can we do to stop this again"*
>
> OM – *"they're coming up with the suggestions"*

[MD & OM, company organisers' feedback, 7m] *“one of the biggest changes is the mentality of the people, right across the board – we're interfering when we need to but they're driving it themselves – that's the main change I've noticed”*

[OM, company organisers’ feedback, 9m]

“They're saying things like why are we doing this – and at some levels rather than just asking it they're doing something different instead.”

[OM, company organisers’ feedback, 9m]

During the company organisers’ feedback session, the MD and OM talked a great deal about the changes in mindset they had observed. The second and third quotes above, which were made about the Lean implementation as a whole, indicate that the participants are helping to drive the implementation and that some feel empowered to make improvements as well as suggestions, which indicates that the empowerment aspect of the implementation was successful and the company was receptive to it. In the first quote, the OM states that **the environmental additions were successfully integrated, and “Lean with environmental improvements” has become part of the company mindset** [I7-41].

Overhead impacts

“I think by being Lean and working more effectively and having less raw materials around and having to spend less hours building up stock and obviously you’re going to spend less raw materials, less electricity, less natural resources, and those things combined, I think they work much more effectively than if it’s just one by itself. By being Lean, by doing these kind of things, automatically has a knock-on effect on the environmental things. Absolutely yes”

[OM, participants’ feedback, 5m]

“…if we become so effective we can reduce the amount of hours we work in a day, we don’t have to run the lights, waste electricity, waste a lot of water, heating – so by working more effectively then you are obviously reducing the amount of resources you are using”

[OM, participants’ feedback, 6m]

These two quotes are discussing what might be called “overhead impacts” – environmental impacts are caused by the factory running, for lighting, heating etc. Therefore, **a Lean implementation which results in more efficient working and a reduction in overtime will automatically reduce the “overhead” environmental impact by reducing the need for the factory to be running while people are working overtime** [I7-42]. The idea of “overhead” environmental impacts had not been suggested by the researcher – this was an idea fed back to the researcher from the company.

Future implementation of “environmental impact reduction and Lean”

Continue and Sustain

> *“we then need to be saying those are the measures, what are our sustain activities – our audit program, how we run that, how we implement it, and then how we make sure it keeps happening which is down to discipline and routine and sustaining it. And then also, as part of our responsibility in managing, is to be constantly cascading that information, either as information or new things that we learnt… …there’s an example of something that we did and it had this impact, or there’s an example of something that someone else is doing that is quite interesting out there in the world, now can any of you think about how we could use that?”*

[MD, company organisers’ feedback, 42m]

> *“I see that as the same implementation on this range of principles, one of which we’ve said is that from our start point, one of which is making it all sustainable, by considering the environmental impact of what we’re doing”*

[MD, company organisers’ feedback, 1h30]

The MD and OM agreed that for the foreseeable future they would be continuing to work on the implementation of 5S begun in the case study. They felt that to implement it fully, deeply and sustainably would take a lot more work, and also agreed that the work done up to the point of the feedback meeting had generated a mass of ideas and improvement actions which will take time to assess and implement [MD, company organisers’ feedback, 1h25] The MD also felt that they have as yet only gained “cosmetic” benefits and have still to gain the deeper benefits [MD, company organisers’ feedback, 1h27].

They stated that environmental impact reduction will be an integral part of the continuing integration [MD, company organisers' feedback, 1h31].

KPI selection

> *"*(at the initial discussions about integration) *we focused quite specifically on environmental KPIs, but what developed further downstream was a much more holistic program within which there was a strong recognition of the environmental impacts and benefits of doing the wrong thing. And therefore if we're looking at this holistic thing which has some strong environmental outcomes… are the set of KPIs, that we were talking about when we were just talking about the environmental impacts of Lean, is it right to separate them out like that or do we need to look back at what we did and say right, we were there, we've changed a lot of stuff, now as part of the final two Ss, what are the things we're actually going to measure, and keep measuring as part of our sustaining program?…within that there will almost undoubtedly be some element of environmental impact…. …that won't be a measure of the environmental impact of sustainable Lean – it will be just one of the portfolio of measures of what have we actually changed and are we maintaining our change and continuing to improve it?"*

[MD, company organisers' feedback, 16m]

> *"They need to be simple, pithy, easy to see in an instant, and easy to create and not taking loads of time to create. And it probably wants to be five things on a board downstairs – or ideally a screen, that did it in real time."*

[MD, company organisers' feedback, 19m]

> *"I think given our size and scale and so on, it's probably not worth a huge amount of layers upon layers. I think that five indicators that everybody out here knew that one way or the other they could affect – if we got that right, would also be five indicators that when we're sat up here looking at the budget for the next year… … we can see a trend… …then that one thing has affected them because they're doing it… …and is also fulfilling the business need. I don't think it's necessary to have*

layers and layers, and I'd want to get away from having layers and layers because I think that would be a muda in itself"

[MD, company organisers' feedback, 22m]

"the shift of mentality is a massive change and that's happened. There's four things there that are good business measures, good business activities. But in relation to the shift in mentality of a whole bunch of people, pretty much everybody… ….that's a massive thing, and there are four bits of detail that are coming out of it. And I kind of think - any others? Well there's the massive thing and then there'll be lots of things that will be probably to some extent difficult to identify and quantify – but they're simply the outcome of people thinking about doing things differently"

[MD, company organisers' feedback, 30m]

"how do you sustain the environmental bit if it's not clear within the whole gamut of this thing that is called "change of mentality". And that's got to be down to having the right KPIs, which I think is interesting then that I questioned and you questioned the original set of KPIs – so we need the right KPIs and they need to address all the factors that we can apply labels to – which is productivity, space, inventory, environmental, etc."

[MD, company organisers' feedback, 41m]

There was a definite feeling that the KPIs as set were not quite performing in the way the company wanted them to. The SMED exercise showed that environmental impact reductions can be made in categories where it was not expected that more impact reduction could be made; the organisers felt that they were unlikely to be able to make further reductions in material usage and so had discounted this as a KPI and yet the SMED exercise may produce a further significant reduction. Company H and company B had some common and some different criteria for the KPIs, but shared with them a sense that **goal selection and selection of measures are important factors to get right, but they are difficult to resolve** [I7-43]. The nature of KPIs for environmental improvement, and the method for their selection, requires further research.

These quotations also show that the company plan to continue to integrate environmental improvement into the Lean implementation and are discussing ways to do so. What was clear was that they would continue in broadly the same pattern as for the case study, starting from the basis that **Lean provides a framework for making improvements which can apply to environmental improvements** [I7-44], but what will change is the way in which environmental and other goals or KPIs are set to drive and sustain improvement.

Problem-oriented workshops

> *"rather than having a dedicated environmental impact reduction workshop to generate ideas, you have a dedicated workshop to look at the problem of scrap handling on setup on the primary process. And you would involve the people who do it, people in engineering, the environmental angle, the money angle, someone from the technical side. And you would get in here and you would say these are the things we need to do, we need to save money for the company, make quicker, more effective, speedy changeovers, waste a lot less material because it costs £x amount per tonne, and save the planet. Now how are we going to do that? On a specific thing. I think it would be problematic to get people who have got quite broad purviews together and say how are we going to save the planet? - because that's not our job as (company H) . But if we have something specific to aim at, and we have our 5 KPIs, which are scrap, electricity (two other things) and environmental impact, and we get together to discuss a project – like how do we shift from compressed air, which we know is an expensive way of achieving motive power, to something else, in order to (achieve all our KPIs) – how are we going to do that guys? I think to be effective they have to be much more focused than just dedicated environmental impact reduction, so they have to fit into the thing… otherwise you run the risk of people sitting around and talking about stuff – and some good things will come out of it - but they'll be divorced from other activities that we're doing, just because that's the nature of how they come about."*

[MD, company organisers' feedback, 1h03]

> *"It's a focus on the business approach rather than a separate thing."*

[MD, company organisers' feedback, 1h06]

These quotations were made in response to a question from the researcher about whether a dedicated environmental impact reduction workshop would be a good thing, as the participants had generated suggestions during the feedback session but did not report doing so during the implementation. The OM agreed that there was a need for reminders but felt that this could be achieved by including some impact reduction criteria for broader problem-solving workshops.

The quotations support finding I7-37, **(environmental criteria should simply be treated as part of the range of criteria or goals for the Lean implementation)** and also show a concern that environmental impact should not be allowed to dominate imrovement efforts; however the OM broadens this concept by stating that considering environmental improvement in isolation is less effective because it is then divorced from other activities, and he believes that improvements are most effective when the criteria are considered holistically (see [I7-36] **By simultaneously considering both environmental and Lean impacts of solutions to problems, a solution would be found that was both "greener" AND Leaner than had either one of the criteria been considered in isolation**). The OM is agreeing with the concept of workshops but suggesting that the company might run workshops focussed on solving problems that have been identified, rather than to generate general suggestions for improvement on only one of the criteria.

4th and 5th S and environmental implications

> *"…now as part of the final two Ss, what are the things we're actually going to measure, and keep measuring as part of our sustaining program? …within that there will almost undoubtedly be some element of environmental impact… ...that won't be a measure of the environmental impact of sustainable Lean – it will be just one of the portfolio of measures of what have we actually changed and are we maintaining our change and continuing to improve it?"*
>
> [MD, company organisers' feedback, 16m]

During both case studies the researcher felt that there was a need to remind participants of the criteria for Lean in their workplace, which was not being met. The MD felt that this was something that came into the 5th S, "Sustain" – where the processes and procedures are put into place that ensure that people do not forget what they are supposed to be looking for, and that the trend for improvement is maintained with further improvement rather than stagnation or back-sliding [MD, company organisers' feedback, 38 min]. This supports findings I7-17 (**There is scope for considering environmental improvement within 5S**) I7-40 (**environmental improvement criteria could be used holistically alongside the other business criteria as the foci for the 5S implementation)** and I7-37 (**environmental criteria should simply be treated as part of the range of criteria or goals for the Lean implementation**).

Environmental Champion

> *"That might be something to emerge out of the sustain stage. I'd be quite keen to avoid that at this stage, where there's a general motivation to keep going and doing stuff and changing it, because there can also be a tendency if you nominate a champion for people to think "oh, that's his responsibility, I'll just get on and do this, that's their job, they can sort it out". So at the stage where everybody is still going for it, where people are quite hands on and still doing it… …where we're still getting the changes we said we'd get from it, then I think that maybe as you get into the sustain stage, and you get people who then come into the business who haven't been exposed to that and they'll pick up stuff from the people around them – and some people will then ease back from the cusp of adventure and settle a bit – and maybe at that stage you have a champion"*
>
> [MD, company organisers' feedback, 1h21]

The role of the champion might start in the sustain stage, as a trainer for new staff, someone who is sent for training in new tools, and also as someone who reminds people of environmental tools they could apply in solving general problems – particularly as time goes by and they might well have forgotten. The risk is that if the champion were appointed too early (before the concept of it being everybody's job to look for opportunities to reduce all kinds of waste) then it might discourage people from making the effort to identify these wastes. Therefore, **a champion for the environmental criteria might be a good idea if appointed at the correct time, to assist**

with training new staff, to act as a fact finder for new environmental improvement ideas and techniques, and to remind problem-solving teams of the environmental tools and criteria [I7-45]**.**

Participant reactions

Environmental wastes

The participants' feedback session was one month after the original training. At this session there was no response from any of the participants when asked if they could remember the "environmental" goals. However during the training sessions the day after the types of waste were introduced, when the trainer asked participants to recall the types of waste, the first response was environmental waste.

The MD's response to the fact that the goals were not recalled was quite interesting –

> *"The fact that no-one could remember the environmental impacts – they kind of don't need to recognise them as specific things, because they're now thinking from a challenging things point of view, and whether it's environmental or job-related or machinery-related or "how clean the floor is" related, they're thinking about it. So when it comes to turning things off, one of the things I think they're probably not thinking is the specific detail of the seven, eight, nine wastes, whatever – but they are recognising that whatever that thing is, I don't need to categorise it into one of these things I just need to know that's wrong, we need to do something different."*

[MD, company organisers' feedback, 10m]

This was a theme that recurred several times in the MD's comments. For example, later in this session -

> *"The right thing is the right thing – it doesn"t matter what category of muda it's in.... those things are useful for getting that shift in thinking but once they're thinking about doing the right things and challenging doing the wrong things, the categories don't matter"*

[MD, company organisers' feedback, 11m]

He suggested that the waste categories are mostly a teaching tool and while they are very useful in achieving the change of mind set Lean requires so that participants see as wasteful some of the activities that they had previously considered normal, once that change of mindset has been achieved it is actually wasteful to spend time working out which category something that is wasteful fits into. Thus, because he had observed the participants in this case making changes that reduced waste (of various kinds, including the environmentally wasteful) he was not concerned that they could not remember the waste categories or the environmental goals. The MD's comment states that the perception of the organisers is that **the participants have been taking actions to reduce environmental wastes along with other Lean wastes because they now perceive these as "the wrong things to do", even though the participants do not report these actions** [I7-46].

Ease of training & trainers' opinions

The external trainers reported that they could see the fit and the sense in combining environmental impact reduction efforts with the Lean implementation [I7-47]. When asked for his comments after presenting the training, the trainer who had presented the section of the training that had the majority of the environmental additions said he felt this material fitted in well and he was happy with it. He felt it was best to focus on company benefit as the environmental issues can be emotive and contentious, and prolonged discussions are time-consuming and not very productive.

The external trainers were asked for their views on running a dedicated "environmental" workshop, based on the fact that during the feedback session the participants generated several new ideas when asked to focus specifically on this area. They felt that time devoted to looking specifically for these issues might be well spent.

They were also asked to give their opinion on treating environmental goals as just another part of the business goals, using the Plan, Do, Check, Act (PDCA) procedure etc. to solve environmental problems, and responded that they felt this would work and made sense.

They felt that they would like to find out more about the potential competitive advantage there might be in reducing environmental impacts.

7.7 The negative case

A method for minimising bias is to actively look for evidence that disagrees with emerging themes within research, and to ensure that the research findings takes these negative cases into account. The researcher has done this throughout the research. In this phase, the negative cases were sought out during the original pass through the data and once again after completing the main process, in the second pass the researcher specifically sought out negative comments. The following negative cases are identified for this phase.

Firstly, the difficulty in assigning useful goals and measures meant that environmental improvements were to be reported by participants and not measured which meant that it was not possible to be really sure what had changed as a result of the additions to the implementation. Secondly, and linked to this, is that the reported actual changes that could be directly attributed to the additions to the implementation were quite small at the end of the case study. The OM commented on this in the feedback sessions:

> *"Lean always works in favour of environmental but environmental doesn't work in favour of Lean – or not always"*
>
> [OM, Company organisers' feedback, 2h 08]

> Researcher – *"so did the addition of the sustainability stuff change anything?"*
>
> OM – *"well, we were probably more aware.* (Before the training) *we were not as aware as we are now, so we probably would have missed a couple of things, I would have thought. Realistically, what we would end up with* (without the environmental additions) *would be the same things as what we've got now that we are aware of it. If we'd done it just environmental, a lot of things we've done wouldn't have happened, if we'd just been trained in how to be more environmental"*
>
> [OM, Company organisers' feedback, 2h09]

The MD replied that his observations were that changes were being made but were likely to be incremental changes and neither assigned to a specific waste nor reported. It should also be noted that measurement would have its own problems (it can be difficult to assign changes to eliminate the effect of other changes for example changing production rates or weather conditions can affect electricity consumption).

The nature of the research questions chosen meant that the company reactions to the concept were of more interest for this research than numerical data about what changed, and in fact the difficulty that the company had in setting measures and goals was an interesting finding in itself. The findings drawn reflect these points (for example, I7-29 There was an increase in awareness and a change in mindset brought about by the training; I7-31 There was some progress towards the chosen environmental goals, but it was limited; I7-33 Environmental improvements had been made through a series of small changes which might add up to significant change but were hard to recall and report; I7-43 goal selection and selection of measures are important factors to get right, but they are difficult to resolve)

Two suggestions were made which the company did not adopt during the case study. The first was the addition of environmental impact indicators to value stream maps. The MD could see potential benefit in doing this, but no such exercise was carried out. The second was the suggestion of a champion to guide integration of environmental improvement with Lean; this, the MD felt, might be beneficial at a later stage but not until staff were accustomed to the idea that environmental impact reduction was part of everyone's job, just as other Lean improvements are. Findings I7-10 (There is potential for the addition of environmental impacts to value stream maps to be useful, but environmental value stream mapping makes most sense as an addition to an existing map or when one is being created) & I7-45 (A champion for the environmental criteria might be a good idea if appointed at the correct time, to assist with training new staff, to act as a fact finder for new environmental improvement ideas and techniques, and to remind problem-solving teams of the environmental tools and criteria) reflect these negative cases.

7.9 Chapter findings summary

The aim of the case study was to use the intervention to provide part of the answers to the research questions. Below is a summary of the case study's contribution to the answers to these questions.

Research question 1 - If there are synergies and similarities between Lean and environmental improvement, what are they?

I7-1 A company implementing “environmental impact reduction and Lean” should involve the whole supply chain

I7-34 Lean encourages the consideration of the whole value stream of a product and it is helpful to consider environmental impacts at all stages as well

Research question 2 - How can the synergies between Lean and environmental improvement be used to inform integrated implementation?

I7-2 Learning to see wasteful environmental impacts in activities that have been accepted as normal is a transition, just as learning to see Lean wastes is

I7-10 There is potential for the addition of environmental impacts to value stream maps to be useful, but environmental value stream mapping makes most sense as an addition to an existing map or when one is being created

I7-11 Goals must have a financial benefit as well as an environmental one

I7-12 The goals must be things that the participants they were selected for could act upon within the normal scope of their role

I7-13 Goals selected should be suited to incremental continuous improvements rather than one off step changes

I7-14 The goals had to have the potential to affect both environmental and financial or operational

I7-15 The company had decided that they would integrate environmental waste as a ninth waste.

I7-16 Additions could be made to the regular audit checklists to include environmental improvements in best practice

I7-24 Suggestions for environmental impact reduction can be integrated into Lean suggestion schemes.

I7-25 It would be beneficial to include an environmental element in a practical training exercise

I7-39 It is possible to standardise best practice for environmental impact reduction

I7-40 Environmental improvement criteria could be used holistically alongside the other business criteria as the foci for the 5S implementation

I7-44 Lean provides a framework for making improvements which can apply to environmental improvements

Research question 3 - What happens when Lean and environmental improvements are made together?

I7-3 The labels that are chosen to identify tools can affect ease of understanding

I7-4 Different companies might find different labels work better even if the concept is the same

I7-5 The environmental additions suggested are a good fit with Lean

I7-6 The idea of integration was acceptable

I7-7 It was easy to understand the proposed integration of Lean and environmental improvement

I7-8 There is a benefit in reducing the number of different programs running

I7-9 Examples of effects and education of the workforce can be used instead of very high-granularity measures and cascaded goals to drive behaviour change and link top-level goals to everyday actions

I7-17 There is scope for considering environmental improvement within 5S

I7-18 Integration with Lean encourages companies to question the fundamentals of their manufacturing methods for environmental and financial benefit

I7-19 Environmental additions can be integrated smoothly into existing Lean training material

I7-20 An experienced Lean trainer can ad-lib environmental additions to the training in addition to his own Lean points

I7-21 The participants were able to identify environmentally wasteful activities and apply the training in practice to some extent

I7-22 Participants seemed mostly to be focussing on fairly simple “overhead” type impacts

I7-23 Participants think the environmental wastes are important

I7-26 Trainers and participants were giving consideration to environmental impacts without prompting

I7-27 There are environmental improvement side-effects from a standard Lean implementation

I7-28 There is potential for SMED to reduce environmental impacts

I7-29 There was an increase in awareness and a change in mindset brought about by the training

I7-30 Participants can generate environmental improvement suggestions when prompted, and can identify the root cause of problems causing excessive environmental impact

I7-31 There was some progress towards the chosen environmental goals, but it was limited

I7-32 Because of the environmental additions to the implementation the organisers were more aware of the environmental impact reductions they had made

I7-33 Environmental improvements had been made through a series of small changes which might add up to significant change but were hard to recall and report

I7-35 If a problem is considered using both Lean and environmental improvement criteria holistically neither would be likely to inhibit the other

I7-36 By simultaneously considering both environmental and Lean impacts of solutions to problems, a solution would be found that was BOTH “greener” AND Leaner than it would have been, had either one of the criteria been considered in isolation

I7-37 Environmental criteria should simply be treated as part of the range of criteria or goals for the Lean implementation

I7-38 There is environmental impact inherent in doing the wrong things and conversely, doing the right things means environmental impact is minimized

I7-41 The environmental additions were successfully integrated, and “Lean with environmental improvements” has become part of the company mindset

I7-42 Lean implementation which results in more efficient working and a reduction in overtime will automatically reduce the “overhead” environmental impact by reducing the need for the factory to be running while people are working overtime

I7-43 goal selection and selection of measures are important factors to get right, but they are difficult to resolve.

I7-45 A champion for the environmental criteria might be a good idea if appointed at the correct time, to assist with training new staff, to act as a fact finder for new environmental improvement ideas and techniques, and to remind problem-solving teams of the environmental tools and criteria

I7-46 The participants have been taking actions to reduce environmental wastes along with other Lean wastes because they now perceive these as “the wrong things to do”, even though the participants do not report these actions

I7-47 The external trainers reported that they could see the fit and the sense in combining environmental impact reduction efforts with the Lean implementation

7.10 Chapter conclusions

This chapter has set out the data gathered during the planning, implementation and feedback meetings of the early stages of a Lean implementation, based on 5S and SMED. The planning included discussions about training, goal setting and the selection of suitable measures. Key stages in the implementation were training participants to recognise and deal with Environmental wastes, practical exercises and waste walk, the use of 5S to “blitz” an area, the use of SMED to identify improvements, and the generation of improvement suggestions from SMED, 5S and waste walks.

The key findings are presented in sections 7.4, 7.5 and 7.6, along with associated discussion and the evidence that lead to these findings, in order to show that they are reasonable.

Interim findings from this case study are drawn from company decisions and organisers’ and trainers’ comments during the planning stages, participant reactions during the training and early supervised implementation, participant, organiser and trainer feedback sessions and the results and effects of integrated implementation.

It was noted that again, goal setting was important and that environmental impact reduction could fit into the Lean framework for improvement, but also that setting the right goals is quite difficult and that it was hard to assess the extent of changes that were made directly as a result of the additions. At the end of the case study it seems likely that the changes made were not that large, but at this stage it seemed equally important to the company that attitudes were changing, "Lean with environmental improvement" was becoming part of the working culture, and participants were becoming empowered. They expected to make more improvements later on and were planning to continue and improve the integrated implementation, foreseeing a great deal of work ahead of them to begin to see the real benefits of Lean.

The holistic, linked nature of environmental improvements and Lean were stressed during this case study; environmental improvement, like Lean, is part of doing the right and sensible things, they complement each other and can act together as criteria for improved solutions.

Section 7.9 presents all the interim findings for this case study, grouped by the research questions whose answers they inform. Methods for bias avoidance are set out in section 7.3.2. Each phase of the planning, implementation and feedback is then set out, explaining and discussing what happened, the observations made and any interim findings that could be drawn. Section 7.7 sets out the negative cases.

8 Final Synthesis

Chapter Overview

The final synthesis chapter summarises all the key observations from the three research phases (literature review, interviews and case studies), organised by themes that were identified as they emerged.

The chapter begins by explaining the synthesis method used, then the themes are discussed in depth, and observations (for example suggestions for future work) and findings (answers to research questions and suggestions for practitioners) relating to each theme are highlighted. The discussion for each theme includes the evolution of the findings from the data. Finally, negative cases and generalisation are discussed.

Please note that research findings generated from the final observations will be presented in the conclusions chapter (chapter 9) in the form of answers to research questions, contribution to knowledge and suggestions for future work.

Chapter aims

The aim of this chapter is to draw together the observations from all stages of the research and to set out clearly and discuss the final observations that can be drawn from them.

Notation used in this chapter

The notation used was as follows:

- Final observations and findings are given as statements that answer one of the research questions or relate to further work or recommendations for practitioners. They are highlighted using bold text, and given a reference number afterwards in the form [Fx-y], where x is the theme number and y is the numerical order of the observation as it appears in the theme discussion text.
- Interim observations from previous research stages are referenced as [Ia-b] where a is the chapter number and b is the numerical order of the observation as it appears in the discussion text in the relevant chapter.

- Quotations from case studies are given as [company, person, meeting, time] with the same abbreviations being used for people as were used in the relevant chapters.

8.1 Introduction to Final Synthesis

The observations from the two case studies, the interviews and the literature were discussed in their relevant chapters more or less separately, without reference to each other, with a view to bringing all the observations together in this penultimate chapter. It was felt that this structure was easier for the reader to follow and allowed each stage to be discussed in its own right, and then all stages to be compared and contrasted together at the end. The intention is that the chapter relating to each stage focuses mostly on what the data says, but that the synthesis compares and contrasts all the data and builds up a picture of what it means.

8.2 Synthesis method

The observations highlighted during the data-gathering phases (interviews and case studies) and the literature review were compared and similar, linked or contrasting observations were grouped together. Where an observation applied to more than one of these groups, it was duplicated.

It could be seen that the observations fell into twelve groups or themes that had evolved over the course of the research. For each of these themes, the relevant observations and sub-themes were used to consider whether answers to the research questions could be drawn from the evidence gathered during the research. Sections 8.3 to 8.14 present the observations and discussion for each of these themes.

8.2.1 Bias avoidance

Section 3.7 (Methodology chapter) presented techniques for avoidance of bias that were used at various stages in the research. This section explains which of these were felt to be appropriate to the generation of findings from the data gathered during the research.

Where possible, findings were drawn from more than one source, e.g. in order of preference - from more than one stage of the research, or from more than one source within that stage, or more than one person at that source.

Peer debriefing was used throughout the research - the researcher had a variety of sources of support and venues for discussion with fellow researchers. The methods used to generate findings and the findings themselves were discussed and checked with the research supervisor.

The researcher looked actively for any data that disagreed with or modified the findings or emerging themes. This is presented in section 8.15 below.

Observations are discussed fully, explaining how they were generated from the data and observations from the research stages, with quotations and references to the comments made, to allow readers to decide for themselves that the findings are reasonable.

The findings relate to generic Lean implementations as they might be carried out by other companies, not to company-specific processes or methods.

Also, the aims of the research were selected to avoid bias. There was no pressure on the researcher to "prove that integration works" because of the research questions selected – the aim was exploration using the integration as a common setting. This is discussed further in chapter 3.

8.3 Theme 1 – Some environmental improvement occurs as a side effect of Lean implementations

In all the data-gathering phases of the research, it was found that there were some environmental improvement side-effects of a Lean implementation [I2-1, I4-11, I6-30, I7-27] or in other words, there can be environmental impact reductions made as a result of Lean implementations where there is no intent to make those environmental impact reductions. In the case studies, it could be seen that some of the environmental improvements made would probably have occurred even if the implementation had continued as normal (without the environmental additions) [I6-30, I7-27].

The literature review revealed mixed results from authors setting out to investigate the statistical links between adoption of Lean practices and environmental performance, with some finding strong links, some finding weak links, some finding no links at all, and some finding negative influence (i.e. areas where Lean behaviours appeared to increase environmental impact). Researchers sometimes gave speculative reasons for these results but rarely had direct research to back up the speculations.

The results from authors carrying out qualitative research, and from the interviews and case studies carried out in this research, identified a number of mechanisms by which Lean might reduce environmental impact as a side-effect.

Where Lean leads to a focus on improved quality, there is an environmental impact reduction all the way down the value stream of a product [F1-1], simply because there is inevitably an environmental impact associated with the production of each component and decreasing the proportion of scrap components reduces the overall number that must be made to produce the required number of good products [I2-13]. A right first time initiative would aim to reduce failure rates in this way (Klassen and Whybark, 1999; Sarkis, 1995) and so does single piece flow - although statistically the latter shows only a weak link to reduction of impact (Rothenburg et al., 2001). During the interviews, five of the ten companies stated that they had reduced scrap and/or waste to landfill during their Lean implementation. In the second case study, company H initiated a project as a result of a Single-Minute Exchange of Dies (SMED) exercise during the Lean implementation that would reduce scrap production by rationalising machine set-up [I7-28]. The OM commented on the cumulative impact reduction all the way down the value stream.

Lean can lead to a reduction in the amount of materials used and/or the use of more benevolent materials. During the interviews, it was found that two companies had also reduced the amount of material in their components or the amount of waste and the impact of the material used. One company had reduced amounts of cleaning solvent used.

Lean encourages the reduction of inventory and buffer stock, which can lead to a reduction of wasted materials and thus a reduction of the associated life-cycle impacts, by reducing materials that go out-of-date (Ross and Associates, 2000). Kanban can be a way of rationalising the inventory held, but can also have other environmental benefits because custom designed, reusable packaging is often used with Kanban systems, resulting in less packaging waste (Ross and Associates, 2000). In the first case study, company B elected to introduce reusable packaging with the key aims of reducing damage (which will also reduce impact due to scrapping of damaged parts) and improving component presentation.

Lean aims to reduce time spent in transport which can have an effect in reducing the total transport emissions both internally and externally (Ross and Associates, 2004; Womack, 2005), although more frequent deliveries may increase them. One of the interview respondents commented that without Lean they would almost certainly have had to move their operations to a lower cost economy off-shore, which would have brought impacts due to shipping products back to the UK.

Lean can reduce overheads which have associated environmental impacts. Initiatives such as kanban, JIT, inventory reduction and buffer reduction can reduce the floorspace required by the business, which has financial and operational benefits but can also reduce the environmental impacts associated with heating and lighting the area [I2-5]. Company H noted that they reduced their impacts by reducing the requirement to work overtime – therefore they reduced the length of time during which the plant was running and therefore reducing not just the heating and lighting requirement but also energy requirements to run air compressors and other plant [I7-42]. During the interviews, three companies reported that Lean had reduced their overhead impacts due to floorspace.

Interview responses showed that four companies had reduced their electricity consumption in some way during their Lean implementation.

In summary, this research confirmed that **standard Lean implementations can reduce environmental impacts due to a focus on quality, reduction in material use or use of more benign materials, reduction of inventory or buffer stock, reduction of transport time, and a reduction in "overhead" energy use** [F1-2].

The side-effect improvements themselves are just as valid, but the lack of intention is an important dimension of this theme. It implies that companies would not seek out further improvements [I2-2, I7-32], and there are, potentially, more benefits to be had by looking for more fundamental improvements (see section 8.14, theme 12).

Theme summary

F1-1 Where Lean leads to a focus on improved quality, there is an environmental impact reduction all the way down the value stream of a product

F1-2 Standard Lean implementations can reduce environmental impacts due to a focus on quality, reduction in material use or use of more benign materials, reduction of inventory or buffer stock, reduction of transport time, and a reduction in “overhead” energy use.

8.4 Theme 2 – Lean and environmental wastes

Carefully defined wastes, and the identification and reduction of waste in the workplace, are very important to Lean thinking and Lean implementations. Environmental impact reduction focuses on reduction of use of materials, energy, water etc. and there is often a focus on not wasting these resources. Some interview participants commented on this similarity, particularly when asked for their comments on the similarities they saw between Lean and environmental impact reduction [I4-6], and respondents from both case study companies commented on it too [I6-33, I7-38], but most authors only seemed to mention it in passing if at all [I2-8]. In general, it can be said that **the definition, understanding, identification and reduction of waste is important to both Lean and environmental impact reduction** [F2-1].

Having acknowledged this synergy the obvious question is how environmental waste in the Lean sense should be defined. Lean’s definition of waste is general enough to be applicable to a range of manufacturing situations but is still specific enough to make it fairly easy to identify the wastes in a given workplace. The wastes contribute to the overall goals (such as to make the company more profitable, or to reduce the production timescale) but their scope is such that they apply to everyday work. **The creation of definitions of environmental waste that would be meaningful on the shopfloor could improve the connection between overall goals and everyday work** [F2-2] [I4-16, I6-10]. The OM at company B commented on the need for intermediaries similar to the Lean wastes, that would relate the overall environmental goals to everyday actions -

> *“It’s like, we need a more profitable business… you don’t measure profit of section x and section y, you measure what they’re doing etc.… and I think we’re in that situation with energy - I don’t really want to get embroiled in measuring the energy usage of each piece of kit that we’ve got in the manufacturing unit because there’s probably 952 bits of kit and how much is that going to cost to put that into place?”*

[OM, metrics discussion mtg, 17m45]

- but it was discovered that this is not a simple task [I6-5] (the setting of suitable goals is discussed further in section 8.8, theme 6, below).

Examination of the Lean wastes also shows that **there are environmental impacts associated with the standard Lean wastes** [F2-3] [I4-7, I6-17] and **companies can choose to integrate the consideration of environmental waste into their Lean implementation either by defining new wastes to add to their list of Lean wastes, or by highlighting the environmental elements within the existing wastes** [F2-4]. Company B chose the latter option. They discussed the possibility of adding another waste but they had comprehensive material already prepared and printed for the Lean implementation and the addition of an extra environmental waste would not really have been practical, and they felt that highlighting the environmental elements of existing wastes was a suitable method. Company H preferred to add an extra waste of “environmental impact” [I7-15]. There appear to be benefits to both options – the addition of an environmental waste category can be useful as a reminder to look out for these wastes, but highlighting the environmental aspects of other wastes means they are inherently well-integrated and also encourages participants to seek environmental wastes in activities that are wasteful in Lean terms [I6-34].

A generalised definition of environmental waste might begin with consideration of the wasteful use of resources and environmental impact that does not add value [I6-11]. The implication from this, and the previously noted environmental impact elements within the existing Lean wastes, is that **companies should first seek out the environmental impacts present in wasteful activities** [F2-5] and act to reduce them, just as they do Lean wastes [I6-18]. At company B some organisers were clear about this in discussions, but it seemed that others felt that impacts were linked to core processing equipment and therefore were difficult to reduce without large scale capital expenditure [BB1, organisers’ feedback meeting, 25m50] – whereas the integration with Lean should suggest that the best place to look for environmental waste is where one looks for Lean waste - in the activities that are not adding value. Companies may need to be encouraged to do so by having this link made explicitly [I6-35].

The interviews showed that learning to see waste is an important transition for participants learning about Lean methods for the first time [I4-23], and drawing the parallel between Lean and environmental waste made it clear to the case study companies’ implementation organisers that **participants (and organisers) need to Learn to see environmental wastes in the same way that they Learn to see Lean wastes** [F2-6] [I6-20, I7-2].

The MD at company H pointed out that the categorisation of waste is of most value to participants as a learning tool and a prompt to look out for particular kinds of waste, but that they should not have to assign wastes to a category once this learning has been achieved. He felt that participants should simply identify environmental wastes as part of “the wrong things to do”; the continued classification of wastes identified does not really achieve any purpose and is therefore wasteful in itself [I7-46] –

> *“The right thing is the right thing – it doesn’t matter what category of muda it's in.... those things are useful for getting that shift in thinking but once they're thinking about doing the right things and challenging doing the wrong things, the categories don't matter”*
>
> [MD, company organisers’ feedback, 11m]

Effectiveness of the integration of environmental wastes (for example, participant reactions and ability to identify environmental wastes) is discussed in theme 11, section 8.13, and the use of Lean wastes as a mechanism for integration is discussed further in theme 4, section 8.6.

Theme summary

F2-1 The definition, understanding, identification and reduction of waste is important to both Lean and environmental impact reduction

F2-2 The creation of definitions of environmental waste that would be meaningful on the shopfloor could improve the connection between overall goals and everyday work

F2-3 There are environmental impacts associated with the standard Lean wastes

F2-4 Companies can choose to integrate the consideration of environmental waste into their implementation either by defining new wastes to add to their list of Lean wastes, or by highlighting the environmental elements within the existing wastes

F2-5 Companies should first seek out the environmental impacts present in wasteful activities

F2-6 Participants (and organisers) need to Learn to see environmental wastes in the same way that they Learn to see Lean wastes

8.5 Theme 3 – Mapping

All phases of the research supported the idea that mapping could have uses in environmental improvement. The potential uses of value stream mapping for the purpose of reduction of environmental impact were discussed in some papers [I2-9]. In the interview phase it was found that mapping was used and valued by some companies in their Lean implementations, and that therefore it would be a valid candidate for adaptation; and further, that the benefits that companies described from mapping might help fulfil requirements for environmental impact reduction [I4-3, I4-24].

The benefits and uses for value stream mapping and thinking from all these sources could be set out as follows:

Mapping helps companies to better understand their processes and value stream, and the life-cycle impacts of their products and components all the way down the value stream [F3-1]. This makes it easier for companies to understand the impacts that are caused by manufacture of products and components, but do not occur within their own processes [I2-9, I7-34]. The MD at Company H discussed the effects of impact reductions made by company H throughout their value stream [I7-1, I7-34]. A similar theme was identified by Simons and Mason (2003), who commented on the value of value stream mapping in avoiding "silos", for both environmental and Lean improvement, focussing particularly on avoiding the danger of transferring impacts between processes rather than reducing the impact [I2-9]. Simons and Mason also propose that companies might gain extra value from their value stream map by adding an environmental impact proxy, gaining many of the benefits of Life Cycle Analysis and gaining more benefit from the work already done in creating the VSM.

Understanding the value stream leading to a process, and the environmental impacts associated with it, can help in educating participants about the importance of their own actions [F3-2] [I6-14]. A method for providing this kind of understanding for participants was discussed early in case 1 by company B's EHSM –

> *"but what you typically would do* (BB1), *is you would typically take a square there* (which represents the process in question) *and you'd say materials in, materials out, and the efficiency of it, because no true process is 100% efficient, so therefore you will lose some product, you will lose something because it's made*

into something else, so therefore my view in this state of utopia would be the person on the track says "yes, I understand that piece of process – it takes in metal and it comes out metal but I lose some metal but I also use energy and I have some noise and I understand the true environmental impact of that". So you're not saying, for every ton I have twenty tons of waste you're saying I understand that that's a value transformation in itself for every bit of kit and I know the value coming in and the value coming out but I also know the wastes involved with building that product. And I think that's where I would like to be - now that is utopia but then for me that means that we've got the awareness bit. Because do we really understand that we're digging something out of the ground and using (xxx amount of) electricity to make (main component part) and then it comes to us and we assemble it"

[EHSM, second agreement meeting, 39m15]

Mapping can help companies understand their current state, define a desired future state, and identify the steps they need to take to achieve the desired state - this could apply equally to environmental goals as to Lean ones [F3-3]. Interview respondents talked about using this method for Lean [I4-24] and it seems that it would also be a useful tool for defining steps to reach a desired state of reduced environmental impact.

The case study companies could foresee benefits from the adoption of mapping for environmental impact reduction, but did not choose to implement it during the case studies [F3-4] [I6-14, I7-10].

Theme summary

F3-1 Mapping helps companies to better understand their processes and value stream, and the life-cycle impacts of their products and components all the way down the value stream.

F3-2 Understanding the value stream leading to a process, and the environmental impacts associated with it, can help in educating participants about the importance of their own actions

F3-3 Mapping can help companies understand their current state, define a desired future state, and identify the steps they need to take to achieve the desired state - this could apply equally to environmental goals as to Lean ones

F3-4 The case study companies could foresee benefits they from the adoption of mapping for environmental impact reduction, but did not choose to implement it during the case studies

8.6 Theme 4 - Lean as a framework for change

Simplistically, it could be said that one aspect of Lean is to provide companies with methods to improve productivity by identifying and removing wasteful activities that have an adverse effect on productivity. It is proposed that **if Lean is considered as a framework for change, then it could also be used as a framework for environmental improvement, helping companies to seek out and reduce wasteful activities that have environmental impacts** [F4-1], and that **the addition of environmental goals and wastes can be used to integrate environmental improvement into the Lean framework** [F4-2].

This proposal is also made by some other authors [I2-4]. In the interviews respondents from companies H and I suggested that the Lean toolkit might be used to tackle environmental impact reduction [I4-25].

The integrated implementation toolset for the case studies was designed on this basis – using the addition of top-level environmental goals to the other goals for the implementation, and either adding environmental waste to the list of Lean wastes or pointing out the environmental elements of the existing wastes, and allowing these additions to filter through to the elements of the implementation's Lean framework as appropriate (e.g. training, waste walks, CI schemes, kaizen blitz events, 5S and SMED) – goals and targets are discussed further in section 8.9, theme 7, and wastes are discussed in theme 2, section 8.4. Both companies agreed with the proposed structures with only minimal changes, and were satisfied with the way that this integration worked (e.g. [I7-44]).

A benefit of integrating environmental improvement into the Lean framework is that it reduces the number of different campaigns running within the company [F4-3]. Both the case study companies responded positively to the suggestion that integrating environmental improvement with Lean reduced the number of campaigns running within the workplace, reducing the requirement for the workforce to learn the vocabulary, systems and methods for different campaigns that they are required to take part in [I6-3, I7-8, I7-24].

Theme summary

F4-1 If Lean is considered as a framework for change, then it could also be used as a framework for environmental improvement, helping companies to seek out and reduce wasteful activities that have environmental impacts

F4-2 The addition of environmental goals and wastes can be used to integrate environmental improvement into the Lean framework

F4-3 A benefit of integrating environmental improvement into the Lean framework is that it reduces the number of different campaigns running within the company

8.7 Theme 5 - The adoption or adaptation of particular tools for environmental impact reduction

In the literature review discussion of tools was prevalent, but in the interviews and case studies the discussion was more focussed on the aims and ideas of Lean, with tools being discussed more as a way to achieve a task once Lean ideas had identified a need to make a particular kind of change. There was a dislike of Lean “jargon” amongst some interview companies and attempts to integrate should bear these points in mind [I4-2].

Discussion of tools in the literature was mostly about the environmental impact reduction side-effects of the tools and this is dealt with in section 8.3, theme 1.

During the case studies, it was found that **it is possible to integrate environmental improvement goals with Kaizen blitz, 5S, Single Minute Exchange of Dies, Continuous Improvement and suggestion schemes** [F5-1].

Value Stream Mapping (see section 8.5, theme 3) was discussed and was used at company B, but without environmental additions – it was not used at company H. Both case study companies used Continuous Improvement and suggestions (see section 8.10, theme 8) and interview respondents also discussed their benefits.

Kaizen blitz [I6-23] and 5S [I7-17, I7-40] were the main Lean tools used by companies B and H respectively as the basis for their implementations. Integration of environmental impact reduction was predominantly by means of the addition of environmental goals (see section 8.9, theme 7) and educating the workforce about environmental wastes (see section 8.4, theme 2), using these Lean tools as a framework for making changes (see section 8.6, theme 4). The potential of kaizen blitz for environmental improvement was also discussed in the literature review and interview chapters [I2-6, I4-3].

Company H used SMED to make improvements in one particular area, producing an idea which will result in one of the largest impact reductions from their integrated implementation, should it receive approval for the required capital expenditure [I7-28]. This is probably a "side-effect" improvement (see section 8.3, theme 1) because it is likely that it would have come about anyway, without the environmental additions. The environmental additions may contribute to justification of the project however, by making the company aware of costs that they may not have considered otherwise. The literature review revealed suggestions about side effects of SMED for environmental improvement, but during the interview phase, company H's OM suggested that the methods used in SMED could be used to look for opportunities to reduce environmental impact –

> *"SMED as well… that whole analysis of each little thing you do that goes into the big thing and then questioning why you do that – why don't you make that easier to get to? Or eliminate it completely by doing something else… you could then apply that to how you are using electricity…"*

[Company H, 2-47m]

This was an interesting suggestion which was not formally trialled in the case study, but is nevertheless worthy of mention.

Root cause analysis was not used formally, but participants at company H were showing a tendency to look for root causes of the problems they identified during the feedback session. There were discussions during both case studies of ways to incorporate the environmental additions into existing or new visual management systems.

Theme summary

F5-1 It is possible to integrate environmental improvement with Kaizen blitz, 5S, Single Minute Exchange of Dies, Continuous Improvement and suggestion schemes

8.8 Theme 6 - Lean as a foundation for change

It is suggested in the literature that Lean acts as a foundation for change (including environmental improvement), and makes companies more likely to adopt environmental improvement programs in two ways [I2-16, I2-17]. Firstly, the experience of implementing Lean creates a cultural change, making waste of any kind unacceptable, and teaching the workforce to accept change. Secondly, Lean helps companies to identify the financial case for improvement projects so they are more likely to identify the financial benefits of environmental improvements.

This research supported the first suggestion - that **the experience of implementing Lean creates a cultural change, making waste of any kind unacceptable, and teaching the workforce to accept change** [F6-1]. Certainly very little resistance to the idea of integration of environmental improvement with Lean was evident when introducing the idea during the interviews and case studies, and respondents seemed to readily pick up on the idea of environmental waste, although it is not possible to say conclusively that this was caused by a cultural shift in the companies having experience of Lean. In case study 2, organisers self-reported that Lean had created a cultural shift within their organisation - participants were questioning their normal procedures and processes and making improvements on their own initiative, neither of which were likely to have happened before the implementation [I7-18]. This attitude was also being extended to environmental improvement – it is a slightly different scenario to that suggested in the literature, because the company had not done Lean very much before this implementation, but there is some similarity between the two effects.

There was a mixed response to the question in the interviews about whether environmental improvement was a cost or a benefit to companies, so it seemed that the experience of implementing Lean does not necessarily predispose companies to viewing environmental improvement as an opportunity, although the interview companies did identify examples of financial benefits from environmental projects. However, both the case study **companies began to consider the costs of environmental wastes when setting environmental goals for the integrated improvement** [F6-2] [I7-14], and it is a short step from there to consideration of the value of improvement.

In the case studies, both companies used the cost of wastes associated with the environmental goals to justify projects [I6-29] (in company H, costs relating to environmental impacts were going to be used to help justify a project identified during a SMED activity – it was difficult to be clear whether these costs would have been identified without the environmental additions to their Lean implementation however) and where environmental suggestions were made, they were easily integrated into the systems for prioritising suggestions and possible improvement actions that were generated by Lean, and analysing their costs and benefits [I7-24]. Therefore, this research supported a slight variation on the theme of the second statement. The integration of environmental improvement suggestions into Lean suggestion schemes is discussed further in theme 8, section 8.10.

This research suggested another mechanism by which Lean provides a good foundation for environmental improvement. Both the case studies and the interview responses suggested that **it might be easier to make environmental improvements once initial Lean improvements had been made** [F6-3], because these steps make it easier to see and understand the key processes. [I4-19, I6-31, I6-32, I7-39].

Theme summary

F6-1 The experience of implementing Lean creates a cultural change, making waste of any kind unacceptable, and teaching the workforce to accept change

F6-2 Companies began to consider the costs of environmental wastes when setting environmental goals for the integrated improvement

F6-3 It might be easier to make environmental improvements once initial Lean improvements had been made

8.9 Theme 7 – Goals and measures

The literature review showed that some authors noted that **both Lean and environmental improvement programmes require goals** [F7-1], and several went on to suggest that **integration of environmental improvement into a Lean implementation can be initiated by the introduction of environmental goals** [F7-2] [I3-10]. The rest of the research supported these observations as follows.

The interviews confirmed that companies usually set goals to direct their Lean implementation, and some discussed the use of goals to drive their environmental improvement programmes [I4-15].

The case studies used the addition of environmental goals to initiate integration and begin an exploration of how companies would find this concept in practice.

The interviews and case studies produced some suggestions about the criteria for the selection of goals:

- Goals must drive desired behaviour [I4-16, I6-7, I6-13]. The OM at company B in particular stated emphatically (during both the interview and case study) that **the point of goal selection is to provide an incentive for people to behave in a way that achieves the desired results** [F7-3] – if a goal does not have any effect on behaviour, it is useless.
- Goals must be sufficiently granular and must be measurable [I6-9]. Participants need to be able to see the effects of their actions and efforts to improve, in order to tell whether they are being effective and to receive positive feedback and feel that the effort is worthwhile. This means that there must be something to measure against each goal, and it must be possible to measure it at a local enough level (e.g. a cell or line) for the participants to feel it does reflect their efforts. Company H suggested that as it was not cost-effective for them to make sufficiently granular measurements of electricity usage, for example, they might achieve the same motivation by educating their participants effectively so that they could believe that the sum of the incremental effects of all their actions lead to an effect on the overall company-wide measure. When considered together, these observations suggest that **with respect to environmental improvement in particular, participants in general need to know that their efforts and actions have some effect in order to be motivated to act** [F7-4]
- Goals must be achievable within the normal role and remit [I4-18, I6-7, I7-12]. It was important for companies when setting goals that they could visualise the actions that a participant might make to have an effect on the goals they were set and ultimately achieve them.

- Goals must be audited [I4-17, I7-16]. Environmental officers interviewed stressed the importance of auditing on environmental goals, and both case study companies intended to integrate the environmental goals into their audits – in the case of company H, this was to be done when they initiated their auditing system, as at the time of the case study they did not have an official one. Auditing is important in Lean because it checks that progress is maintained and that there is continuous improvement, but there was also a perception during the case studies that **there is a need to show that managers felt the environmental goals were important** [F7-5]
- Environmental goals for Lean should also make sense financially and operationally – ideal environmental impacts to target are those that are also expensive [I4-13, I7-11, I7-14] (see also section 8.8, theme 6)
- Environmental goals for Lean should be suited to incremental continuous improvements [I7-13]

Case study companies found it easy to set top level goals (e.g. reduce electricity usage) and they could see what was necessary to make them accessible for participants, as summarised above, but they found it very difficult to imagine participant goals that fitted all the requirements, even after quite lengthy discussion, and this issue was not really resolved [I6-5, I7-43] – part of the aim of the case studies became to work out how to resolve this issue. Company B's suggestion was to set a required outcome of a given number of environmental improvement projects from each of their kaizen blitz type events [I6-45], and company H found the case study showed the need to put much more thought into their whole system of goals including the type of goal set, measuring, auditing, feedback and education [I7-43].

Reflecting on the whole of the research it is interesting to note that the role of "goals for Lean improvement for participants" actually seems to be filled by the Lean wastes. Overall goals may be set for Lean implementation stages – a given reduction of throughput time, cost or failure rate, for example – and the wastes act as ways to relate the overall goals to improvements in everyday work practices, which the participants can relate to, and which will contribute to the achievement of the goals (see F2-2). This also suggests that the perceived need for workforce level goals is really showing that **there is a need for a better definition of Environmental wastes** [F7-6].

Theme summary

F7-1 Both Lean and environmental improvement programmes require goals

F7-2 Integration of environmental improvement into a Lean implementation can be initiated by the introduction of environmental goals

F7-3 The point of goal selection is to provide an incentive for people to behave in a way that achieves the desired results

F7-4 With respect to environmental improvement in particular, participants in general need to know that their efforts and actions have some effect in order to be motivated to act

F7-5 There is a need to show that managers felt the environmental goals were important

F7-6 There is a need for a better definition of Environmental wastes

8.10 Theme 8 - Workforce involvement and continuous improvement

Workforce involvement and continuous improvement schemes (those which provide a system to record and action suggestions from the workforce), and the potential advantages they could provide for an environmental improvement program, were one of the more popular themes in the "environmental impact reduction and Lean" literature. Authors stated that continual small improvements are more effective than "radical innovations" (Soltero and Waldrip, 2002) and that there is improved ownership of, and buy-in to, improvements suggested by the workforce, and that by encouraging the whole workforce to make suggestions, the company can fully benefit from the combined experience, knowledge and creativity of the workforce [I2-6].

The interviews showed that companies felt that the workforce involvement element of Lean was integral to its success [I4-20], and reported useful improvements generated by the workforce via CI suggestion schemes [I4-22].

During the case studies, participant and organiser feedback sessions showed that **participants understood the integration of environmental impacts into Lean** [F8-1] [I6-26, I6-46, I7-21, I7-29, I7-30, I7-41, I7-46]. Both companies accepted the suggestion of integration of environmental improvement categories into their suggestions schemes very readily [I6-23, I7-24]. Participants were able to generate suggestions for improvement during feedback meetings when they were prompted to do so [I6-26, I7-30], so this research supports the statement that **the workforce can make environmental improvement suggestions as well as Lean ones** [F8-2]. At company H, a number of environmental suggestions were generated alongside the standard Lean ones, and were easily integrated into the system of prioritising and processing suggestions [I7-24]. Company B planned to incorporate environmental improvement into their newly set-up suggestion scheme by the addition of environmental categories to the existing Lean categories on the suggestion cards, which would then also allow environmental suggestions to be processed at the same time and in the same way. Additionally company I explained during the interview phase that they were actively encouraging environmental suggestions within their suggestions scheme. Therefore, this research shows that **environmental improvements can be made via Lean suggestion schemes** [F8-3] and companies implementing Lean will generally have systems for recording suggestions and improvement ideas and analysing their costs and benefits, which can also be applied to suggestions for environmental improvement.

At company H, the MD reported that Environmental improvements had been made through a series of small changes which might add up to significant change, so this research supports the suggestion that **environmental improvement can be made incrementally, in the same way as Lean continuous improvement** [F8-4]. Since there were not direct measures against the environmental goals, incremental improvements may have gone unnoticed as they were hard to recall and report [I7-33], and the effect this may have had on the recorded effects of the integrated implementation is discussed in section 8.13, theme 11.

Theme summary

F8-1 Participants understood the integration of environmental impacts into Lean, and can generate improvement ideas

F8-2 The workforce can make environmental improvement suggestions as well as Lean ones

F8-3 Environmental improvements can be made via Lean suggestion schemes

F8-4 Environmental improvement can be made incrementally, in the same way as Lean continuous improvement

8.11 Theme 9 – Education and training

Given the importance attached to workforce involvement in Lean implementations (see section 10, theme 8 above), and the acknowledged need to learn to see environmental wastes as well as Lean ones (section 8.4, Theme 2), it follows that **participants need training on both Environmental and Lean goals and wastes and how to use the Lean tools to address them** [F9-1]. This training was one of the stages of the case study outline proposed to companies and the discussion focussed on how to do it – it was taken for granted by the companies that it was necessary.

It was found that **environmental additions can be integrated into the Lean training** [F9-2]. The details of training and additions to the training slides were developed in collaboration with the case study companies. The companies agreed that the training needed to identify the environmental improvement goals and explain their importance, explain what actions participants could take in order to fulfil the goals, and the tools that could be helpful.

While designing the training, the following points were felt to be important –

- It was important to find ways to make the training memorable. At company B, in particular organisers felt that **it is helpful if participants are given ways to visualise the scale of environmental impact relating to the goals** [F9-3] **-** the environmental waste goals were presented with associated trivia-style facts associated with the impacts, and one participant at company B commented a few days after the environmental training session on one of these (comparing the amount of waste taken to landfill in the UK to the volume of the Albert Hall in London), showing that it had made some kind of impression upon him – possibly because it gave him a way of visualising the impact [I6-22, I6-24].
- The point was made at company B that **understanding the scale of the company's emissions, especially compared to the emissions of an average home, might help participants to adopt environmental impact reduction at work as well as at home** [F9-4], and how their own individual actions contribute to the company's impact, and what they can do to reduce it.
- At various points the EHSDM, CSPSC and EHSM all suggested that **explaining to participants how actions they can take can contribute to achieving the company's environmental goals can**

be a motivating factor that encourages participants to act to reduce environmental impacts [F9-5] [I6-21, I6-40].

- A final training design point was selection of terminology. **The terminology selected needs to fit in with the company's existing Lean and environmental vocabulary, if any, and it must be unambiguous** [F9-6]. In order to integrate well and gain the most benefit from reduction of the number of campaigns within the company (see F4-3, section 8.6, theme 4), the environmental additions had to use the same terminology as the rest of the Lean material. The terminology used also has to fit in with any company communications policy on the environment. Finally, participants must understand the terms selected and they must not be confusing - for example, the term "environmental waste" might have been chosen for waste or *muda* associated with environmental impact –but this could have been confusing as the term is also used by council refuse collectors to mean garden and compostable waste. [I6-6, I6-19, I7-3, I7-4]

The case studies demonstrated that **Lean trainers** (such as the external consultant's trainers working at company H for the duration of the case study) **can happily present the training and can integrate environmental points** [F9-7], and that **there are sometimes practical difficulties in integrating environmental additions seamlessly into existing material** [F9-8]. At company B, for practical reasons, it was necessary to run the environmental training as a separate session (although still within the training phase of the implementation) and it was not possible to integrate the environmental goals into other printed material and slides, which were quite extensive. At company H, the environmental additions were made quite evenly throughout the training slide presentation [I7-19], and there was less material and more emphasis on the trainer's ad lib discussions and explanations. At company B the trainers rarely mentioned the environmental goals and although the response from participants was positive during the feedback session, there was rarely any action on the goals in the practical phases of the work; during these phases the trainers prompted the participants in areas relating to the other goals but not the environmental ones. At company H, the trainer emphasised all the goals, including the environmental ones, quite evenly, as appropriate throughout his presentations and discussions – during the training design phase he was happy to include environmental points in the training material, but also added them where there were no prompts, in general discussion sections during the training sessions [I7-20], and participants generated more environmental actions during the practical parts of the implementation although they still generated new ones during the feedback session [I7-21, I7-26].

The feedback sessions with companies also generated some proposals for improving the training, as did observations made by the researcher during the training. These were as follows -

- **The inclusion of the environmental goals in the games and exercises should be possible and beneficial** [F9-9], but was not specifically planned in the case studies and was minimal in case 1 and slightly greater in case 2 (see also section 8.13, theme 11) [I6-27, I7-25]. In line with the point made above and in [F2-6] (section 8.4, theme 2), companies accepted that participants need to make a mental transition to see that there is a need to change the processes and procedures that have been normal to them, and encouraging them to analyse and question all these previous normalities, to look for environmental wastes and potential improvements. It was noted that participants seemed to really understand the ideas of Lean when they were able to practice applying them in exercises (including the waste walks described in chapters 8 and 9 – see sections 8.5.1 and 9.5.1), games, and guided implementation phases, and these seemed to help them make this mental transition of learning to see, for the Lean wastes.
- **Trainers and participants both benefit from the inclusion of reminders about the environmental goals, throughout the training material if possible** [F9-10]. At company B, where the environmental improvement message was only disseminated in a dedicated training session and the rest of the training was quite prescribed, trainers stated that they forgot to include points about environmental improvement; on the waste walk the researcher observed, the trainer prompted the participants to look for standard Lean wastes but not the environmental wastes. Participants generated suggestions when prompted but had not done so previously and it seems likely that this was because there were no reminders to do so [I6-25].
- **More examples would be helpful** [F9-11]. Organisers at company B would have liked more examples of environmental improvements that could be made, because participants can look for the same wastes or improvements in their workplace, before moving on to finding new

wastes and improvements for themselves [I6-41, I6-42] and examples set the scale of expectation for the implementation. Examples were provided in the training, but they were quite general and therefore rather limited in scope, and this might be why the scope of suggestions made was also quite limited (see section 8.12, theme 10). Company H also felt that giving participants examples of how typical actions and improvements that the participants might make could affect the company's improvement goals might be a better way to drive the desired behaviour changes than the use of very granular goals [I7-9], which might be difficult to set and expensive and time consuming to measure – and still not necessarily reflect the effects of changes, as other factors such as the time of year and production volumes also affect some goals (energy usage, for example).

Theme summary

F9-1 Participants need training on both Environmental and Lean goals and wastes and how to use the Lean tools to address them

F9-2 Environmental additions can be integrated into the Lean training

F9-3 it is helpful if participants are given ways to visualise the scale of environmental impact relating to the goals

F9-4 Understanding the scale of the company's emissions, especially compared to the emissions of an average home, might help participants to adopt environmental impact reduction at work as well as at home

F9-5 Explaining to participants how actions they can take can contribute to achieving the company's environmental goals can be a motivating factor that encourages participants to act to reduce environmental impacts

F9-6 The terminology selected needs to fit in with the company's existing Lean and environmental vocabulary, if any, and it must be unambiguous

F9-7 Lean trainers can happily present the training and can integrate environmental points

F9-8 There are sometimes practical difficulties in integrating environmental additions seamlessly into existing material

F9-9 The inclusion of the environmental goals in the games and exercises should be possible and beneficial

F9-10 Trainers and participants both benefit from the inclusion of reminders about the environmental goals, throughout the training material if possible

F9-11 More examples would be helpful

8.12 Theme 10 – Factors for acceptance and adoption

The interviews and case studies showed that **companies' representatives understood the idea of integration readily** [F10-1], and that **the idea of integration was of practical interest to companies' representatives** [F10-2]. Once the idea was presented to companies during the interviews they quite quickly began to suggest ways that it could work in their company. There were very few negative comments on the concept [I4-5]. During recruitment for the case studies, both companies very quickly agreed to participate and the organising teams seemed to grasp the concept of integration and understand it readily [I6-4, I7-6, I7-7] – they quickly saw how Lean and environmental elements could fit together well [I7-5]. The trainers at company H also stated when asked that they felt the environmental additions were a good fit with Lean [I7-47].

The following observations were made during initial presentation of the idea of integration to interview and case study company representatives:

- **Companies' representatives reacted positively to the parallel between Lean and environmental waste** [F10-3] [I4-6, I4-7, I6-33,I7-6].
- **At initial presentations, companies' representatives recognised a possibility of gaining greater benefit for little more effort** [F10-4] [I4-8, I6-2]. Interview respondents reported times when they had had to go back to Lean improvement projects to correct problems with environmental elements (for example, moving work stations around meant lighting was no longer optimal) and that they might have saved themselves effort by integrating considering environmental criteria alongside the Lean ones – and vice versa, that they should consider Lean criteria when making changes for environmental improvement reasons [I4-9].
- Interestingly, only one of the interviewed companies had adopted Lean because of a feeling that the company would no longer be viable without taking urgent action to become more efficient (sometimes called "the burning platform") [I4-14] and likewise, the case study **companies' representatives were willing to integrate**

environmental improvement with Lean even though, while there were incentives and drivers for the case study companies to reduce environmental impacts, there was no overriding imperative to do so [F10-5].

Theme summary

F10-1 Companies' representatives understood the idea of integration readily

F10-2 The idea of integration was of practical interest to companies' representatives

F10-3 Companies' representatives reacted positively to the parallel between Lean and environmental waste

F10-4 Companies' representatives recognised a possibility of gaining greater benefit for little more effort

F10-5 Companies' representatives were willing to integrate environmental improvement with Lean even though, while there were incentives and drivers for the case study companies to reduce environmental impacts, there was no overriding imperative to do so

8.13 Theme 11 – Effectiveness of integrated implementation and possible reasons

The implementations were successful in raising levels of awareness [F11-1] [I7-29]. **Organisers and participants felt that the environmental goals were important** [F11-2].[I6-37, I6-44, I7-23]. Observations F8-1 (participants understood the integration of environmental impacts into Lean) and F8-2 (the workforce can make environmental improvement suggestions as well as Lean ones) (see theme 8, section 8.10) also relate to the effectiveness of the training in raising awareness and understanding.

The implementations also resulted in some reported environmental improvement [I6-28, I7-31], but **the effect on the environmental goals that could be directly attributed to the changes made by integrated implementation was quite small** [F11-3] at this stage [I6-28, I6-37, I7-31]. It is however important to note that difficulties with setting measures against the goals meant that it was impossible to fully measure the effect of the implementation in quantitative terms [I6-5, I7-43]; this is significant because it is likely that some of the improvements might be small, incremental changes that might not be reported [I6-28, I7-33, I7-46]. Some improvements were made as a side-effect of other activities, but would probably have happened had a standard (rather than integrated) Lean implementation taken place [I6-30, I7-27]; notably, the reduction in overhead impacts that was reported at company H [I7-42]. However the environmental goals did contribute to the justification for one project which would have environmental benefits [I6-29].

A number of factors may have limited the effect so far on the environmental goals, as follows:

- It was early in the implementation. This could affect the results in a number of ways. Firstly, the company may give priority to the traditional Lean goals at first, to solve big productivity problems and gain savings [I6-31]; it might be easier to identify the environmental problems once Lean has cleared away some of the wastes that make it hard to see and understand the processes [I6-32]; It was noted that the environmental impact reductions made at the early stage were similar in scope to the early Lean improvements made, so Lean might be encouraging a focus on “housekeeping” that accounts for the smaller-scale propositions that are being suggested.
- Both the case study implementations used games and exercises to help participants understand how to put into practice the theories that had been taught and explained. At company H the trainer referred to the environmental goals where appropriate, so at some points they did become part of the exercises, while at company B the researcher did not observe any mention of the environmental goals outside the dedicated training session. It was noted at both case study companies how effective these games and exercises were, and participants often seemed to make a step change in understanding and enthusiasm over the course of them. It might help participants to understand and remember the environmental goals if they were better integrated into existing or new games and exercises [I6-27], and if in general they received more reminders to act on them (in the same way that they are prompted to act on the traditional Lean wastes) [I6-25]. See also [F9-9] (section 8.11, theme 9).
- It was noted at company B in particular, that the suggestions made during the feedback session tended to be similar to the examples provided during the training session of ways of acting on the environmental wastes described. As these were not company specific

they tended to be rather limited in scope, and it seemed that this set the expectation for the kind of impact reductions that could be made. Examples that explore the more fundamental processes and wastes within the company might set this expectation differently and encourage participants and organisers to make more fundamental changes [I6-41, I6-42]

- It is possible that the message about reducing environmental impacts at home (for example by recycling, wasting less water and turning off electrical appliances when not in use) has been so effectively disseminated to the general public (for example by television advertising campaigns) that participants find it hard to think of other environmental impacts at work; certainly many of the environmental suggestions were along the lines of such advertising campaigns and local council initiatives [I7-22].

The case study at company B showed that **integrated implementation is not sufficient on its own to integrate working practices of Lean and EHS functions in different departments** [F11-4]. Interview responses showed that existing levels of integration (i.e. in companies that do not integrate environmental improvement with their Lean implementation) between environmental and Lean functions in companies is low. People working in either department may have been aware of some of the activities the other department was involved in, through informal communication with colleagues, formal report meetings, or company internal communications (e.g. noticeboards or magazines) but did not often work together [I4-4]. The first case study and literature review backed this up – Company B's Lean and environmental teams knew each other and knew of some of the work the other department had done, but had never tried to carry out joint projects intended to benefit both functions. During the implementation the EHS manager and BB1 worked together to generate ideas [I6-16], but no-one in the Lean team would contact the EHS manager if not prompted to do so by the researcher, and at the end of the integrated implementation the departments were not appreciably closer together. The Lean department were still not involving the EHS manager or his team in Lean activities [I6-38], although they were planning to continue to include an environmental improvement element in their activities [I6-43].

The second case study was rather different, because the MD was responsible for the company's environmental policies and the Lean implementation – but he had not thought to combine the two prior to taking part in the interview stage.

Both companies were making plans at the end of the case studies for ways to refine and improve the integrated implementation and carry it forward [I6-43, I7-41] suggesting that **after a trial implementation, companies perceived potential benefits from integrated implementation** [F11-5].

Theme summary

F11-1 The implementation was successful in raising levels of awareness

F11-2 Organisers and participants felt that the environmental goals were important

F11-3 The effect on the environmental goals that could be directly attributed to the changes made by integrated implementation was quite small

F11-4 Integrated implementation is not sufficient on its own to integrate working practices of Lean and EHS functions in different departments

F11-5 after a trial implementation, companies perceived potential benefits from integrated implementation

8.14 Theme 12 – Holistic integration

Lean could be considered to benefit from a holistic view in several ways, and this research suggested the following benefits for the integrated implementation.

The interviews and case studies showed that **Lean and environmental criteria are usually intertwined; it is unlikely that a change intended to affect one will have no affect on the other** [F12-1] [I4-8, I4-9, I6-36, I7-36]. Also, there are intrinsic links between Lean and environmental wastes (for example, electricity usage has an impact on the environment but is also expensive and its wasteful use might be linked to some of the seven wastes) [I7-38]. Therefore, companies can save effort by considering both criteria when making any change. Also, the addition of environmental criteria may actually show up wastes that have an effect on traditional Lean goals, but that the traditional implementation might have missed [I2-3].

The interviews and case studies showed that **staff working in Lean and EHS functions or roles can work together using their combined**

knowledge to create solutions more quickly or to create better solutions [F12-2] [I4-10, I6-16].

The MD at company H stated at the end of the case study that he felt that **integration produces solutions that better fulfil the existing Lean criteria as well as the environmental criteria** [F12-3] that were added, if all the criteria are considered simultaneously and with equal weighting [I7-37], because the problem solvers have to put more thought into their solutions and must explore more options [I7-36]. He felt it was unlikely that environmental and Lean criteria would conflict if considered in this way [I7-35].

Theme summary

F12-1 Lean and environmental criteria are usually intertwined; it is unlikely that a change intended to affect one will have no affect on the other

F12-2 Staff working in Lean and EHS departments can work together using their combined knowledge to create solutions more quickly or to create better solutions

F12-3 Integration produces solutions that better fulfil the existing Lean criteria as well as the environmental criteria

8.15 Negative case

As discussed above, a method for minimising bias is to actively look for evidence that disagrees with emerging themes within research. The researcher has done this throughout the research. Negative cases relating to the intermediary observations from which the final observations are discussed in sections 4.5, 6.7 and 7.7, and negative cases relating to the final observations made in this chapter are as follows.

F2-5 states that companies should first seek out the environmental impacts present in wasteful activities. Some organisers at company B made this statement and it follows from the final observation that there are environmental impacts associated with the standard Lean wastes [F2-3]. As discussed in this part of section 8.4, theme 2, other organisers did not seem to apply this thinking to environmental impacts (especially electricity usage) in practice, although they had been present when the environmental impacts associated with standard Lean wastes were discussed and had not queried this statement. It seemed more likely that these organisers had preconceived ideas about where environmental impacts occurred and had simply not made the link between Lean waste and environmental impact in this way, than that the observation was incorrect. The observation is accompanied by the comment that participants and organisers may need to be encouraged to look for environmental impacts in wasteful rather than value-adding activities and processes.

Similarly findings are drawn about ways that mapping could be used, based on the opinions expressed by case study company organisers and interview respondents, even though the case study companies did not choose to use mapping for environmental impact reduction during the case studies. F3-4 (The case study companies could foresee benefits they from the adoption of mapping for environmental impact reduction, but did not choose to implement it during the case studies) accompanies the observations regarding the potential uses of mapping.

8.16 Generalisation

It is desirable to draw conclusions from the research that are relevant to other companies, not restricted to those where the research took place. Clearly the limited number of companies involved in this research means that generalisation could be an issue. However, the implementation of Lean discussed in interviews and on which the integration was based did not seem to deviate dramatically between companies, nor did these implementations seems markedly different from those described in the literature, and findings and observations were not drawn from any company- or product-specific activities. The Lean trainers involved in the second case study had experience of Lean implementations at many different companies and their opinion, when they were asked about generalisability of integrated implementation, was that it would be applicable outside of the research setting.

8.17 Conclusions

This chapter draws together the observations from previous chapters under twelve sub-headings or themes, which are: Some environmental improvement occurs as a side effect of Lean implementations; Lean and environmental wastes; Mapping; Lean as a framework for change; The adoption or adaptation of particular tools for environmental impact reduction; Lean as a foundation for change; Goals and measures; workforce involvement; education and training; Factors for acceptance and adoption; Effectiveness of integrated implementation and possible reasons; Holistic integration. Within these headings a total of 54 key observations for this research are set out.

Section 8.15 explains the negative cases and 8.16 discusses generalisation of the research observations.

9 Conclusions

Chapter Overview

This chapter begins by summarising the answers to research questions, then discusses strengths and weaknesses and potential sources of bias in the research and their avoidance. The chapter goes on to discuss the contribution to knowledge, provides notes for practitioners and discusses possible future work suggested by this research.

Chapter aims

The aim of the conclusion chapter is to present a summary of the outcomes or conclusions from this research in the form of the contribution to knowledge, recommendations to practitioners, answers to research questions, and recommendations for further work that resulted from this research.

9.1 Answers to research questions

Research question 1 - If there are synergies and similarities between Lean and environmental improvement, what are they?

- Standard Lean implementations can reduce environmental impacts due to a focus on quality (the manufacture of each component involves impacts all the way back along its value stream, and reducing scrap reduces the parts used and thus the impact per good product), reduction in material use or use of more benign materials, reduction of inventory or buffer stock, reduction of transport time, and a reduction in “overhead” energy use. [F1-2]
- The definition, understanding, identification and reduction of waste is important to both Lean and environmental impact reduction [F2-1] and there are environmental impacts associated with the standard Lean wastes [F2-3]
- Mapping helps companies to better understand their processes and value stream, and the life-cycle impacts of their products and components all the way down the value stream. [F3-1]

- The experience of implementing Lean creates a cultural change, making waste of any kind unacceptable, and teaching the workforce to accept change; this culture makes it easier for the workforce to learn to reduce environmental wastes and to accept the need for this change [F6-1]
- Both Lean and environmental improvement programmes require goals [F7-1]
- The workforce can make environmental improvement suggestions as well as Lean ones [F8-2], and companies implementing Lean will generally have systems for recording suggestions and improvement ideas and analysing their costs and benefits, which can also be applied to suggestions for environmental improvement [F8-3]
- Environmental improvement can be made incrementally, in the same way as Lean continuous improvement [F8-4]
- Participants need training on both Environmental and Lean goals and wastes and how to use the Lean tools to address them [F9-1]

Research question 2 - How can the synergies between Lean and environmental improvement be used to inform integrated implementation?

- Companies can either choose to integrate the consideration of environmental waste into their implementation by defining new wastes to add to their list of Lean wastes, or by highlighting the environmental impact elements within the existing wastes [F2-4], and companies should first seek out the environmental impacts present in wasteful activities, rather than trying to reduce the impact of their value-adding activities [F2-5]
- Environmental additions can be made to Lean training, encouraging participants to make environmental improvements within the Lean framework. [F9-2] Participants (and organisers) need to Learn to see environmental wastes in the same way that they learn to see Lean wastes [F2-6]. Learning to see that activities that have been accepted as normal are actually wasteful and should be removed or reduced, or improved to remove or reduce the wasteful element, is a transition and this is true for environmental impacts as well as for Lean's standard wastes.

- Understanding the value stream leading to a process, and the environmental impacts associated with it, can help in educating participants about the importance of their own actions [F3-2]
- Mapping can help companies understand their current state, define a desired future state, and identify the steps they need to take to achieve the desired state - this could apply equally to environmental goals as to Lean ones [F3-3]
- If Lean is considered as a framework for change, then it could also be used as a framework for environmental improvement, helping companies to seek out and reduce wasteful activities that have environmental impacts [F4-1]; and integration of environmental improvement into a Lean implementation can be initiated by the introduction of environmental goals [F7-2]
- It is possible to integrate environmental improvement with Kaizen blitz, 5S, Single Minute Exchange of Dies and Continuous Improvement and suggestion schemes [F5-1] and environmental improvements can be made via Lean suggestion schemes [F8-3]
- Terminology selected needs to fit in with the company's existing Lean and environmental vocabulary, if any, and it must be unambiguous [F9-5]

Research question 3 - What happens when Lean and environmental improvements are made together?

- Where Lean leads to a focus on improved quality, there is an environmental impact reduction all the way down the value stream of a product [F1-1]
- The case study companies could foresee benefits they from the adoption of mapping for environmental impact reduction, but did not choose to implement it during the case studies [F3-4]
- A benefit of integrating environmental improvement into the Lean framework is that it reduces the number of different campaigns running within the company [F4-3]
- Participants understood the integration of environmental impacts into Lean [F8-1], and can generate improvement ideas [F8-2], organisers and participants felt that the environmental goals were important [F11-2] and the implementation was successful in raising levels of awareness [F11-1] but the effect on the environmental goals that could

be directly attributed to the changes made by integrated implementation was quite small [F11-3]

- Companies began to consider the costs of environmental wastes when setting environmental goals for the integrated improvement [F6-2]
- Lean trainers can happily present the training and can integrate environmental points [F9-6] but there are sometimes practical difficulties in integrating environmental additions seamlessly into existing material [F9-7] – for example where there is already printed material which will be costly to alter, it could be difficult to fully integrate environmental material all through the Lean material.
- Case study company organisers were willing to integrate environmental improvement even though, while there were incentives and drivers for the case study companies to reduce environmental impacts, there was no overriding imperative to do so [F10-5]. Company representatives understood the idea of integration readily [F10-1] and the idea of integration was of practical interest within companies [F10-2]; Company organisers recognised a possibility of gaining greater benefit for little more effort [F10-4]. Company representatives reacted positively to the parallel between Lean and environmental waste [F10-3]
- Staff working in Lean and EHS departments can work together using their combined knowledge to create solutions more quickly or to create better solutions [F12-2] but integrated implementation is not sufficient on its own to integrate working practices of Lean and EHS functions in different departments [F11-4]
- Lean and environmental criteria are usually intertwined; it is unlikely that a change intended to affect one will have no affect on the other [F12-1] and integration produces solutions that better fulfil the existing Lean criteria as well as the environmental criteria [F12-3] if the criteria are considered simultaneously and holistically.

9.2 Sources of bias, strengths and weaknesses and generalisation

The research design selected for this research focussed more on depth than breadth, by working with two companies over an extended period of time and carrying out longer interviews with ten companies. This is a weakness in that involvement of more companies could provide more breadth and more certainty of general applicability; but the greater depth of action research studies with fewer companies was chosen as a key strength, giving a richer understanding of integration in practice.

The action research structure adopted allowed this research to focus on practical applicability of integration; most of the companies interviewed had not thought of integrating Lean and environmental improvement before, so if other methods where the researcher sought to observe without influencing the research setting had been employed, it would have been unlikely that practical application of implementation could have been observed.

The companies taking part in the research were based in various regions of England, active in a variety of sectors, with a variety of manufacturing methods, and on a variety of scales (in terms of size of company and size and complexity of the products they make); however, their small number and the fact that they chose to take part in research on Lean and environmental improvement might mean that they do not accurately represent the views of all manufacturing companies in the UK.

Methods for bias avoidance that were used in this research were discussed in chapter 2, and the specific methods to be used in each stage were discussed in chapters 4, 5, 6, 7 and 8. The selection of research questions that focussed on exploration of integration rather than a requirement to prove that it worked was useful in avoiding subconscious bias against data that might have suggested integration did not work, or aspects that were not so successful, and the researcher was also careful to explain this to participants where appropriate (for example to company organisers) so that they did not feel obliged to withold such “negative” data.

9.3 Novel findings and contribution to knowledge

This research confirmed the link between Lean and environmental wastes, but also clarified an extension to this link – that companies should first seek out environmental impacts in activities that are not adding value [F2-5], because there are environmental impacts associated with the standard Lean wastes [F2-3]. During the case studies, some organisers at company B had clearly grasped this parallel, but others were inclined to limit their search for environmental wastes to their value-adding processes, causing difficulties in the identification of ways to reduce impact.

It was also noted that companies' representatives reacted positively to the parallel between Lean and environmental waste [F10-3]. This idea was a good starting point from which to begin a discussion about integration, allowing an approach to integration to begin on familiar ground.

In general, it was found that the idea of integration could be understood readily, by interview participants and both organisers and participants in the case studies [F8-1, F10-1]. Organisers and interview participants could see, even at initial discussions, how integration would work in their companies and could identify benefits of integration [F10-4]. Case study organisers agreed willingly to the integrated implementation trial that formed the basis of the case studies [F10-2], and were willing to implement even though while there were incentives and drivers for the case study companies to reduce environmental impacts, there was no overriding imperative to do so [F10-5].

For the workforce, the benefit of integration is that it reduces the number of different "campaigns" running within the company [F4-3] to which they are required to give attention alongside their normal value-adding work. Companies are realising the benefits of workforce involvement in Lean and other improvements (notably health and safety and environmental improvement, as noted in the literature) but this can result in a plethora of different schemes with different systems and terminology, which could be confusing. Integration of environmental impact reduction into the Lean implementation gains the benefits of workforce involvement while reducing the diversification of campaigns in the workplace.

Another extension to the "Lean and environmental waste" synergy is the need for participants (and organisers) to learn to see environmental wastes in the same way that they learn to see Lean wastes [F2-6]. Case study organisers recognised this need, and the researcher observed signs of a transition during the second case study, in particular. Company respondents during the interviews nearly always explained that part of the introduction of Lean involved training sessions that showed participants how working practices they had accepted as normal could be improved upon because they were wasteful; it was found that learning to see environmental impacts could be integrated with learning to see Lean waste training, and training on environmental goals and ways to reduce environmental impacts using Lean tools can be integrated into the Lean training [F9-1, F9-2]. It was also found that Lean trainers (such as the external consultant's trainers working at company H for the duration of the case study) can happily present the training and can integrate environmental points [F9-6]

Organisers at both case study companies felt that training should explain to participants how actions they can take can contribute to achieving the company's environmental goals, because they recognised that this can be a motivating factor that encourages participants to act to reduce environmental impacts [F7-3].

The case studies and interviews confirmed that there was some impact reduction as a result of standard Lean implementations, and there was some impact reduction that could be attributed directly to integration but this was quite small at this early stage [F11-3]. It was noted that the environmental impact reductions made at the early stage were similar in scope to the early Lean improvements made, and also related to the messages disseminated about environmental impact reduction at home (increasing recycling rates and turning off electrical appliances when not in use). Companies explained that they would find it useful to have more explicit examples of environmental wastes and ways to reduce environmental impacts within an integrated implementation, and it seems that examples might help to set the scope and expectations for changes resulting from the implementation (F9-11).

Despite the limited scope of directly attributable environmental improvement reported, at the end of the case studies the companies were making plans to continue with integrated implementation, incorporating changes based on learning from the trial implementation; this implied that they perceived benefits, or the potential for benefits, from integrated implementation [F11-5]. In general it was found that integrated implementation was successful in raising levels of awareness of environmental impacts and methods by which the workforce could act themselves to reduce impacts [F11-1].

Organisers at company B discussed how an understanding of the value stream leading to "their" process, and the environmental impacts associated with it, could help in educating participants about the importance of their own actions [F3-2]. The OM at company H in particular, and other interview and case study participants, demonstrated how understanding the value stream helped them to understand that producing a defective product in their own factory had environmental impacts all the way down the product’s value stream, and the company B organisers suggested that incorporating a simplified explanation of the value stream impacts before a process and its own inputs, impacts and outputs, might further increase operators' environmental awareness.

Soltero (2007) states that he believes Lean is a system for problem solving that can be used to achieve many kinds of goals, including environmental improvement goals. This research records practical application of this theory [F4-1] and found that environmental improvement goals can be a method of introducing environmental considerations into a Lean implementation [F7-2] (with the previously mentioned proviso that the improvement directly attributable in the early stages was quite small).

This research showed that it is possible to integrate environmental improvement goals with Kaizen blitz, 5S, Single Minute Exchange of Dies and Continuous Improvement and suggestion schemes. [F5-1] – other researchers have identified side-effects from the use of these tools that are beneficial to environmental improvement and some authors also suggested the deliberate integration of goals with some tools – this research clarifies the latter position.

It is also suggested in the literature that there is an overlap between the work of Lean and environmental / EHS functions. This research showed that staff working in Lean and EHS functions can work together using their combined knowledge to create solutions more quickly or to create better solutions [F12-2]. However the research also showed that adopting integrated implementation is not sufficient on its own to integrate working practices of Lean and EHS functions in different departments [F11-5] – at company B, although representatives of the two departments worked well together when the researcher acted to invite them to meetings and activities, there was no action from representatives of either function to work more closely together without the researcher's intervention.

Other authors have found numerous ways in which Lean and environmental improvement are mutually beneficial and can support each other. This research took this a step further – organisers at the case studies and interview respondents reported that in their experience Lean and environmental criteria are usually intertwined; it is unlikely that a change intended to affect one will have no affect on the other [F12-1].

Finally, this research showed that the consideration of both Lean and environmental criteria simultaneously and holistically produces solutions that better fulfil the existing Lean criteria as well as the environmental criteria [F12-3].

9.4 Notes for practitioners

- It was found during the case studies and interviews that company representatives were receptive to the idea of integration and understood it readily [F10-1, F10-2] they reacted positively to the parallel between Lean and environmental waste [F10-3] and recognised the possibility of gaining greater benefit for little more effort [F10-4]
- Companies can either choose to integrate the consideration of environmental waste into their implementation by defining new wastes to add to their list of Lean wastes, or by highlighting the environmental elements within the existing wastes [F2-4]. Integrated implementations should focus on seeking out environmentally wasteful activities that are outside of the value adding processes [F2-5]. Organisers and participants may need to be reminded of this.
- If Lean is considered as a framework for change, then it could also be used as a framework for environmental improvement, helping companies to seek out and reduce wasteful activities that have environmental impacts [F4-1]
- Integration of environmental improvement into a Lean implementation can be initiated by the introduction of environmental goals [F7-2]
- Criteria for goals –
    - Environmental improvement goals for integrated implementations can be selected via Impacts and Aspects registers, if available – if not, then company cost codes can prove a useful tool to focus discussion of where impacts lie.
    - Top-level goals should be things that Lean can act on (e.g. associated with normal regular working routines) within the area defined and the scope of action of people that work there
    - The point of goal selection is to provide an incentive for people to behave in a way that achieves the desired results [F7-3]
    - With respect to environmental improvement in particular, participants in general need to know that their efforts and actions have some effect in order to be motivated to act [F7-3]

- It is possible to integrate environmental improvement with Kaizen blitz, 5S, Single Minute Exchange of Dies and Continuous Improvement and suggestion schemes [F5-1]
- Value stream thinking is helpful when considering environmental impact reduction, [F3-1], and process mapping can help companies understand their current state, define a desired future state, and identify the steps they need to take to achieve the desired state - this could apply equally to environmental goals as to Lean ones [F3-3]. Other researchers suggest potential for avoiding “silo thinking” and assessing where the highest impacts lie.
- Understanding the value stream leading to "their" process, and the environmental impacts associated with it, can help in educating participants about the importance of their own actions [F3-2]
- Environmental goals can be integrated into suggestion schemes [F8-3] and participants can make environmental impact reduction suggestions through such schemes [F8-2]. Lean suggestion schemes provide a way to collect, record, evaluate and act on suggestions from the workforce relating to environmental impact.
- Participants need training on both Environmental and Lean goals and wastes and how to use the Lean tools to address them [F9-1], and environmental additions can be made to Lean training, encouraging participants to make environmental improvements within the Lean framework [F9-2]
    - Participants need to learn to see both standard Lean and environmental wastes [F2-6]
    - Trainers and participants both benefit from the inclusion of reminders about the environmental goals, throughout the training material if possible [F9-9]
    - It is helpful to give participants a way to visualise environmental impacts and their scale, as this makes them more memorable [F9-3]
    - It is also helpful to show participants how their actions contribute towards meeting company goals [F7-3]
    - Understanding the scale of the company's emissions, especially compared to the emissions of an average home, might help participants to adopt environmental impact reduction at work as well as at home [F9-4]

    - Care should be taken that terminology fits in with other Lean and environmental terminology used by the company [F9-5]
    - More examples would be helpful because participants can look for the same wastes or improvements in their workplace, before moving on to finding new wastes and improvements for themselves [F9-10]. The selection of examples to use should be done carefully, as it seemed that examples contributed to setting the scale of expectation for the implementation; to be most effective in setting an expectation for fundamental changes, the examples need to be tailored to the company's activities and impacts
    - The inclusion of the environmental goals in the games and exercises should be possible and beneficial [F9-8]
- Organisers and participants should be encouraged to consider environmental and standard Lean criteria simultaneously and holistically, to get solutions to problems that meet both sets of criteria better [F12-3]

9.5 Notes for academia

The novel themes in this research chiefly related to the fact that the concept of integration was new to most of the companies involved in interviews and action research; findings on acceptance and understanding could be drawn because the researcher introduced these ideas to nine of the ten companies, including the two companies that took part in the action research case studies, so it was possible to observe first reactions to the suggestion of integration, and the first discussions of ways to integrate deliberately in companies. Integrated training had never before been carried out in these companies, so the training material that the researcher designed or modified had never been seen before in these companies.

In these early stage implementations the environmental impact reductions that seemed to be made because of the integrated implementations were not that large; the literature largely related to more mature implementations, suggesting that these reductions might increase with maturity. Combined with the acceptance from companies and increases in understanding; the extent of the findings and contributions from this research; and the lines of enquiry suggested for future work (section 9.6), it seems that this is an area worthy of further research.

At the initiation of the project, it was envisaged that there was some kind of overlap between Lean and environmental improvement, but the findings suggest that the improvements are intertwined. Lean and environmental wastes are dispersed throughout a company's activities, overlap one another to a significant extent, and are inter-dependent; also, different categories of waste may be more visible to different people at different points in the activities, so the addition of environmental waste considerations to Lean implementations may lead to the reduction of Lean wastes that may not have been so obvious.

The intertwined nature of Lean and environmental improvements and impacts is perhaps at the root of the rationale for integration; actions to affect one are likely to affect the other, and so it seems to make sense to consider both together. In addition, there is some similarity between the activities carried out to reduce environmental impacts and implement Lean (for example, both may use continuous improvement suggestion schemes and may involve some form of mapping of processes), so integration can reduce the workload and reduce the demand made on the workforce to engage with different initiatives in the workplace.

Towards the end of this research it began to seem that the difficulty in setting goals for environmental improvement in Lean might have been more properly overcome by better defining environmental waste. It seemed to the researcher that Lean wastes provided one mechanism to relate the overarching goals of Lean to the everyday work of participants, and this may have been a better expenditure of effort than attempting to define goals that met all the criteria set.

9.6 Future work

First and foremost, since this research showed that environmental impact reduction after the early stages of integrated implementation was quite small [F11-3], it would be useful to study the progression of integrated implementation in more companies and through to greater maturity, and to see whether companies could make changes that were more radical; those that related to a more fundamental change in the way of doing things. This research showed that the environmental impact reductions made at the early stages were similar in scope and scale to the early Lean "housekeeping" improvements, so it would be interesting to see whether the scale and scope of improvements made continues to be similar.

This research suggested but did not prove some other causes of limited scope of early-stage improvements, and this could be an interesting area for future research. These were that it may be easier to make environmental improvements once initial Lean improvements had been made, because these steps make it easier to see and understand the key processes by "tidying up" and removing the bulk of the wastes which can make it harder to identify the potential environmental improvements; that companies may be focussing first on the main productivity problems, and problems relating to environmental impact are less urgent; and that environmental impact reductions suggested were similar to the message widely disseminated about reducing environmental impacts at home.

This research showed that organisers wanted more examples of environmental impact reduction possibilities [F9-10], and that the scope of examples given might set expectations about the scope of changes that could be made. Future research might investigate how best to use examples to encourage more radical changes.

It was noted during the case studies that games and exercises were instrumental, for many participants, in achieving better understanding of Lean. It would be beneficial to develop such games and exercises that integrated the simultaneous consideration of Lean and environmental impact reduction goals [F9-8].

The research also showed that while it was quite easy to select top-level environmental goals to focus on, goal deployment for environmental goals was quite difficult. Companies could specify the criteria for these goals quite easily, but found it much harder to select goals that would fulfil these criteria. Future research could work on developing ways to help companies select such goals.

The case studies showed that there is a need for better definition of Environmental wastes [F7-6] and the development of environmental wastes that work as Lean wastes do, to relate the top-level goals to everyday work without being prescriptive and limiting participants' creativity in identifying environmental wastes in their workplace, might help to fulfil the need to relate top-level goals to shopfloor level work [F2-2].

The research also showed that representatives from Lean and environmental / EHS functions could work well together [F12-2], and that there is a certain overlap between their activities; however, the integrated implementation was not sufficient to encourage them to work more closely together. The researcher suggested the appointment of a champion to foster closer links and more involvement between the two functions, but the case study companies were not willing to make such an appointment. It is key to the success of the integration that the two functions should work better together and future research might investigate methods for encouraging this.

9.7 Conclusions

This chapter has presented a summary of the outcomes or conclusions from this research, in the form of the contribution to knowledge, recommendations to practitioners, answers to research questions, and recommendations for further work.

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Appendix A - Company D Interview transcription

A1 Lean questions (1 – 13)

Researcher – What was the draw of Lean, initially? What got you started on it?

Respondent A – I suppose the real thing that drew us down the Lean route was we changed our CEO in (headquarters) and our new CEO came from a company.... (confusion – demand flow technology or Lean?) we'd done quality circles and we'd always done things to improve but we hadn't gone down a specific route, if you like, we'd always done it in isolation. And then when (CEO) joined the company at that particular time there was a consultation group called JCIT who were doing demand flow technology, that's their trademark. So we started going down the demand flow technology route, which at the end of the day encompasses Lean, you look at your processes, you do synchronisations of your processes, you look at flow – obviously one of the main drivers of demand flow technology was the flow side, looking at reducing flow time, reducing cost, improving quality. So we started going down that route, and unfortunately what we did with that technology was unfortunately what tends to happen if you do it with just the management team went down it, not the workers, none of the workers went down it – the management team came back and tried to do this to the workers and it didn't quite work so it was one of those you get in some factories where we had "oh here's another one, let's see how it works". [Company D, respondent A, 2m] So we started that and then (CEO) came on board and said don't do demand flow technology, you need to encompass the whole thing – and then (MD) joined us three and a half years ago. I mean this is particularly now (Company D). (MD) joined us from (xxx), as he said he'd been trained by some of the gurus from Toyota. They'd been doing quite a bit of Lean at (xxx), he'd been specifically brought in because of the Lean background, and he turned the company around here. So from a (Company D) perspective, we really started doing Lean three and a half years ago.

And the drive I suppose at the end of the day was that with (CEO) on board we changed the focus of the company. Prior to (CEO) we were very much a family-type company, we were going to make our own products in the factory and sell our own products, we weren't going to acquire other companies, we are a privately owned company and it was we're going to keep everything to ourselves and our competition were beating us in some areas. And (CEO) came in and said you need to change your strategy. If you want to stay in the field and competitive, if you want to be the best there is, which our directors wanted to do and we wanted to do, you need to change your strategies. So he made a pledge that within five years we would have tripled our turnover. And we actually tripled it four years after that, a year earlier. So that drove us to say we needed to change our strategies. And we started to acquire companies, because (CEO) said if you want to be the best you have to be the best in all the areas that (company D's product) touches. We have a saying that everything has to have a good feel about it– a good design, it's innovative etc.

So we've expanded and gone into all sorts of new areas, for example marine – we'd investigated the sector before but never gone into it, but we've now got a marine manufacturer on board. We've done that through acquisitions rather than making new designs ourselves. That was the big driver behind it, we've got to go into new markets, we've got to become more competitive, we've got to change the way we're doing things. That's really the main draw.

Question 1 – What instigated your initial interest in implementing Lean?

Company B response summarised by researcher - A new CEO was appointed who had experience of Lean. The company wanted to move into new markets, and had made acquisitions, where Lean was prevalent.

Question 2 – When did you start your Lean implementation?

Company B response summarised by researcher - 3 and a half years ago at that site

Researcher So when did (CEO) join?

Respondent A (CEO)'s been with us now – 5 or 6 years, 2 or 3 years longer than (MD).

Researcher What about experts? Did you hire people in house, or did you use consultants, or something else?

Respondent A What we did, when we started seriously going down the route, after demand flow technology – we did keep a lot of that in, so maybe that's one of the things you want to note. We used a lot of training we got from them. We then brought a lot of people in like (MD) – we've learned a lot from (MD), from a (Company B) point of view. And we do have the Lean champions program – we do so much in house, and then we have an intensive week's course, we've slowed down a bit on that, we're currently on our 10^{th} round of people doing that and it's about 25 people at a time.

Researcher Is that the mentors?

Respondent A (10 mins) No, that's different to what (MD) was talking about. These are Lean champions, they're not exactly facilitators of Lean but champions of Lean, people who will have the advantage of being really intensively trained from external sources as well as internal sources. As we've grown - we started a Lean office here at (Company D) and there were three of us when we started. The idea was that we became experts, we got the books and went on as many training courses as we could, and went to (xxx) and had a couple of days there. We learnt from different people and brought those skills and techniques in house, and started doing events and training and things like that, so we used resources in-house – we started off with consultancies but we tend to do most things in-house now. One thing we learnt – another good name for you is (consultant A) – he has specialised in the accounting side of Lean and (MD) has known him for many years and we've brought him in for seminars. In the early days he pushed us a lot harder than we possibly would have pushed ourselves. He's based in the States but he's an Englishman. He's well worth getting in touch with. We've done these seminar days and we do the Lean champion courses but a lot of our training is by reading and learning ourselves and taking it forwards. At the end of the day Lean is just common sense, it's not rocket science, and it's trying to make people see the common sense side of things again and a lot of what we're doing is just from experience and carrying on. Although I tend to say common sense goes out the window when you come to work.

Question 3 - Was your expert in-house or consultant?

Company B response summarised by researcher - Started off with consultants and still use them, but now they have more in-house expertise (they have also hired staff at all levels with Lean knowledge) staff learn by reading, they learn from other companies and attend seminar days.

Researcher Did you use a recognised implementation plan?

Respondent A The first thing that we ever did, that we said we've got to get in place was the 5S – because obviously 5S is your foundation. So that was the first thing that we tried to really instil into people. And of course 5S covers standard work and visual management so those were the 3 things that we started off with. Visual management obviously tends to drive the others. That's where we started. The Lean champion scheme took us down another route and obviously we had VSM that started driving our kaizen events. When we first started down the route there was a lot of low-hanging fruit and 5S showed a lot of it. We also already knew some areas that we needed to look at. The flow of the facility was important. We'd already been in value streams quite a few years ago prior to starting Lean. I joined the company as a customer service representative in the sales group, and then I moved to (Company D) when I started the quality role. When I joined we were one big company, we had a die-cast plant, a powder coat plant, an injection moulding plant and assembly. And that was us, no thought of flow or anything like that, it was these are our departments and our areas of excellence. And then I don't know what started it off but we thought we've got two different types of manufacturing, we've got metals and plastics – so we split the company into plastics and metals and we did that for a couple of years then for some reason we thought this isn't working, we've got to put this back together. Die-casting went, they needed another plant in America and die-casting wasn't doing the business here that we'd expected, so from a cost point of view it was more beneficial to send it over to the States so we lost die-cast, and I think that was the trigger for us to think the division of metals and plastics didn't really work, so we became one big happy family again. Then (MD) joined and said you had two distinctive manufacturing facilities here so we had (catalogue items) and custom, which is what we call the automotive stuff, and EDC – so he saw the three value streams. The majority of our sales have always been from the catalogue. But we started to win more automotive work and we were doing custom designs for that. And as (MD) said, the automotive work is growing by about 80-90% a year at the moment which is quite extortionate, same in america. But especially in the automotive side, custom designs take quite a lot more work to get into production. So when we were looking at value streams it was quite a straight-forward split in that anything that was going to be custom made went down the automotive value stream. Anything that came from the catalogue, or derivatives of those, would be our (catalogue items) route.

Question 4 - Did you use a recognised Lean implementation plan, or choose the tools that fitted your needs best?

Company B response summarised by researcher – They begin with 5S, then work on setup reduction and flow; VSM drives from there. Their consultant sets objectives for the year.

Researcher Structure of implementation?

Respondent A (20 min) We started with 5S, 5S encompassed naturally visual management, and standard work, then VSM came into place, and with the Lean champion program you have to do so many prerequisites before you go on the training courses which drove down another path. And those prerequisites obviously 5S was one, Setup reductions and flow which covers a lot... oh, and that's the story I was going into. So when (MD) came, and said we're going to go into value streams, and then within the value streams we had to decide what the products were and how they were made and (MD) saw straight away that we had a particular time with the (catalogue items). Automotive was fairly straight forward because it went from moulding into the assembly area and out again, so that was quite straight forward, we weren't too worried about that. But we needed to create a space and we needed to create a clear delineation through the facility that this was automotive and this was (catalogue items) value streams. So we had to split the facility up again. And with (catalogue items), as (MD) showed you, we saw that we'd got different products and we couldn't really mix them, they each had their own little cell. So we then did flow or layout, to actually layout the facility to enable flow and to make sure that we'd actually got the right groups of product together. We originally had 4 groups within (catalogue items) but when we bought (subsidiary company) we moved some products here that they made over here.

But from the structure viewpoint, it was first do 5S then do layout then take it from there. VSM then took us on our journey further from there. This is where we are and this is where we want to be. And then further to that we get these cards each year from (consultant A), so that helps us to say these are the objectives for the whole company, what are we going to do as a facility to make sure that we help drive these objectives forward. And that helps to drive us in the other direction to show where we need to focus our attention from a Lean point of view. So that's the structure. And that model is what we're bringing into the admin side and the leadership side.

> Question 5 - Please can you briefly describe the structure of your lean implementation?
>
> Company B response summarised by researcher – Did 5s first, including standard work and visual management. VSM drives kaizen etc. 5S showed up a lot of the low hanging fruit and already knew some areas that they needed to improve. Value streams pre-existed. Then looked at flow and product families and layout of factory. They use kaizen blitz events. Year on year, the implementation is driven by the year's goals suggested by their consultant.

Tools – see list

Done that one and done that one. Heijunka – we've tried to do but haven't done it as an exact science. We're always very hard on ourselves! We don't call it kaikaku – we've done kaizen though. We've got kanbans – we don't really do JIT. Milk run I suppose is what you'd call our water spiders. We do poke yoke. We do pull-push because we do kanban. People say we do that one, but I don't really believe we do. Root cause we do. Single piece flow has always been at the back, we haven't got much to single piece flow but it's always at the back of it. Set-up reduction – we don't really smooth because it's so erratic. We try and use takt but not 100%. We tried two bin but we've gone back on that. I've never heard of turn-back analysis – we do first pass yield though. We do do value and we do value stream mapping and we do visual control.

Researcher Anything that I missed?

Respondent A First pass yield is more of a metric than anything else. It's how much you make right first time. We use day by the hour which is our visual control. I think all the things we use are encompassed by what you've got up there. We do just do it but that's CI, it's a tool we've given ourselves. OK, we don't call CI Kaizen but we call our blitz events kaizen and we call CI continuous improvement. Transition planning is something that a lot of companies don't use that often but it's a very good long-term planning tool. Lean daily management system which is your – that's from the admin side, from the consulting group, leaders on office kaizen and Lean daily management comes from that area. Think that's it....

Oh there is one. We've got goal deployment. We have a system whereby we take these goals that are sent by (consultant A) and we cascade them down to facility, manager, supervisor, shopfloor worker so this is what the goals mean to each of them. So it's a goal setting cascade. That's quite a useful tool

(MD) had used this at (xxx), and it just seemed to make sense. What a lot of companies don't seem to do is make it clear to everybody how they fit into the great scheme of things. And it's all very well saying to the people on the shopfloor right we're going to drive profitable topline growth but what does that mean to the people on the shopfloor? And this is a way of putting it into simple words, so it (30 mins) says what this means for you is that you have to follow standard work, and make sure you reach your day by the hour figures, and whatever it might be. So it's a good way of making sure that everyone knows what it actually means for them. So yes we've used it and it's been quite good. We have a performance development review procedure and it helps drive that better as well, we all have reviews and our bonus at the end of the year and our pay structure is based on how well we do in our reviews. And it helps to drive that because when we get these goals we know that our own goals for the year are this and it ties back all the way up the chain so it helps to drive that. <u>There's a big poster up in the facility</u>.

Researcher The financial benefits you mentioned didn't you, it tripled…?

Respondent A Yes, our turnover has tripled in the last three years, if not more... that's (Company D). Globally, it's tripled.... but I think it's tripled here as well, we've had quite a bit impact. With (MD) coming on board it's made quite a big difference, it's been quite a big change. (turnover has quadrupled)

The aim was to triple after 5 years but we did it in four.... I think he wants to do it again now!

Researcher Well, I guess you can't stand still can you! So…how do you measure the effects of Lean?

Respondent A It's not a direct measurement but we have a scorecard which we report on monthly and that shows us how we're improving in certain areas like quality, service, productivity so that's our top level measurement, showing us what we're doing with Lean. We aren't very good at keeping on top of the measurements we put in place for kaizen events to be honest, and making sure we sustain it. Something we've done with our CI projects is we have an audit team in place and we audit those projects and keep on doing so once the project is finished, to make sure we're sustaining it. That's something we've introduced in the last couple of years. Because it was obvious that although our scorecard is getting better which is our immediate measurement, so yes we're doing something and we're improving and it's helping, what we don't necessarily do is keep on top of the projects and kaizens we're doing. So the specific ones we're not very good at – in the Lean office we've tried to do it but then as we've grown bigger, we've been spread so thinly that that side of it has sort of fallen by the wayside. We have planning sheets and we try to keep people up to it, but we tend to be drawn to other areas. So the main one is the scorecard and the value streams have a weekly box score meeting. Now the box score is truly an accounting term, and I think I may have a book from (consultant A). It's a specific measurement for a value stream, it's a move away from standard accounting because standard accounting doesn't work with Lean, and this is looking at value stream accounting. Box score is looking at 5 values – dock-to-dock which is looking at how long it takes for products to go through the system; first-pass yield; inventory turns within your particular area; sales per employee; can't think of the other one off the top of my head.

With the transition plan you pick 20 keys and what you do is you then go through five stages, and the first stage is basic, working up to your ideal state. It comes from Toyota but it's all in the office kaizen books too. Not many companies tend to go for the whole hog if you like; everyone tends to go for the shopfloor because that's where you can make the biggest visible improvements. But what people don't tend to think about or see as being a problem is the admin. side or the front-end. A lot of - now that we're going down the route it's quite amazing because it's obvious that a lot of the leadership waste that's happening on the admin. side is causing problems on the shopfloor side. So it's no matter how much you do to improve on the shopfloor, until you do the admin. side you're not going to get that connection. It's a bit of a new area – there are more people getting involved now. And the Lean group have started getting involved in the customer service side of it, which is really admin.

Question 7 - What were the financial benefits you observed? Question 8 - How do you measure the financial benefits? Question 9 - Can you identify why they occurred, and at what stage?

Company B response summarised by researcher – They quadrupled turnover in the last 3 years - globally aimed to triple after 5 years, achieved in 4. They report weekly and monthly on various KPIs, some of which relate to financial effects.

Researcher What would you say are the main changes you observed, more in the processes and the structure of the operation and things like that?

Respondent A The layout was the biggest visual change. Our communication in terms of company metrics was another big one – talking to people some like it and some don't. It's obvious what we've done, with all our metrics and all our visual management we have (40 mins) what we call a site level tracking centre, which boils down to a value stream tracking centre, which then boils down to a cell board. So again we put cards in there, so visual management was quite a big one. 5S was also quite a big change for people. That was about it – I don't think VSM affected too many people as such, it made things more visual for them. <u>Obviously along with that was the cultural change, getting people used to changing the way they do things. The amount of times I've had people saying "I've done it like that for 20 years you're never going to improve it" and we do. As people started getting used to it you started hearing "this really does work" "it's saved me time".</u> [Company D, respondent A, 41m]

Researcher Do you think the language has changed, people have picked up the Lean language?

Respondent A Yes and no – you tend to find it in people that have touched Lean – and a new thing that we started last year is that when we get new people in, I do a four hour Lean induction workshop. Because what's happening is you get certain pockets of people who have learned the terminology because for some reason, for example they've been on a workshop or a seminar, and they've picked up the terminology that way. And then there's other groups of people who haven't been on workshops, haven't been on events and they hear these words and they just haven't really got a clue of what it's about.

So we started the Lean induction – but you can't give people an overview of Lean in half an hour or an hour. So I now do a Lean induction workshop. And as people go through that they are starting to pick up more of the terminology and have a better understanding. But we still have people here who don't know what 5S is – but it's understandable because they haven't been through an induction and no-one's explained to them what it is and what it does. So then eventually they will go through the induction and then they will understand. It's improving but there are still these little pockets where people don't know what it all means.

> Question 10 - What other changes did you observe - more in the way that you run your operation, in your processes and procedures, that kind of thing?
>
> Company B response summarised by researcher – Altered layout is the biggest visual change, communication of company metrics was a big change and so was visual management. 5S was a big change for people, and in general they observed a major cultural change. Some terminology adoption.

Researcher Do you see Lean as a project or a way of life?

Respondent A No – Lean is for life. And it's because in all honesty, of the change. You've got to change culture. And you can't do that as a one off, you have to do it and keep going. And it's also about the sustainment, if it's not a way of life you're never going to sustain it. We've learnt that from our 5S, we've had to go back and back and back over 5S so many times, and even today, I'm not happy with the way 5S is done today. But then that's partly because as I'm growing in my role, I'm seeing a lot more things and becoming more critical of the way we do things here. I have to remember that you have to celebrate the good points and we do have some very good points that we've done here. It's a shame I don't have any photos of what the facility looked like years ago. Bearing in mind I've been with the company 8 years and I've been at (Company D) almost 5 years, it's changed so much since I came over to (Company D). It used to be a rabbit warren literally. We have a canteen with glass walls that looks over the facility and you used to look out of there and think I don't know where anything is, because it really was a rabbit warren. Now you can look out of there and see clear pathways, so even just from the layout we've done a lot. I mean it's never been too bad – the facility was built in '94 so it's still fairly new – 10 years old but it's still a fairly new facility. Powder coat is our dirtiest area of the facility, it's going to be – but yes, we have improved. Quite dramatically.

Question 11 - Do you see lean as a one-off project, or something you will continue to do for the foreseeable future?

Company B response summarised by researcher – Lean is for life - because of the culture change and to ensure improvement is sustained.

Researcher How Lean on a scale of 1 to 10 would you say you are?

Respondent A Compared to what? Like (MD) says we used to think we're about 20% of the way. But as we go down, we think oh no, we could do better at things. So we think we're about 10 – 15%, so if you quote that from 1 – 10 – 1? No. I'd say – we're not quite about half way there so I'd say 3. 3 or 4. It is a very long journey. One thing, I don't know if it is still the case but Toyota have been doing this for 50 years, and they measure themselves on how much value added they do, and I don't know if it's changed or not but the last I heard was about two years ago and they said they're at 17% value added. So if you take Toyota as the ultimate, we're coming up to 1%, so we're quite a way away from that! But we have made a lot of progress.

Question 12 - How lean do you think your company is today - say on a scale of 1 to 10, with 10 being "perfection" and 1 being "not at all lean"

Company B response summarised by researcher – Tentatively, 3 or 4? But they are unsure what to compare themselves to. Their value added is approaching 1%.

Researcher If you were describing Lean in just a couple of sentences, what do you think are the main principles for you?

Respondent A Main principles of Lean for me – there are 5 that I cover in my induction. Basically they cover it all – understanding value from the eyes of the customer; and you need to understand your own value stream; and how that value is then flowing through your value stream to the pull of the customer while seeking perfection. (50 min) The other thing that we say, in a nutshell, is it's making what the customer wants when the customer wants it – no more, no less. [Company D, respondent A, 49m]

> Question 13 - There appears to be no 'one truth' about what lean is. Can you say, in one sentence, what are the principles that make up lean for you?
>
> Company B response summarised by researcher – 5 main principles - understand value from the customer's perspective - being clear on the value stream - flowing the value through the value stream to the pull of the customer while seeking perfection. "Making what the customer wants when the customer wants it."

Chatting while waiting for Respondent B to arrive -

Respondent A - With the european headquarters – and they're taking it over into the facility at the moment too - They're very very keen on making sure the work life balance is right. They do special days – I wasn't here unfortunately, I was over the road – but they've had days when they had a masseuse in, and people can have massages throughout the day. We have more than one canteen in the building – we've got a big canteen downstairs, because the majority of people sit on this floor at the other end, and then upstairs there's an executive canteen and a smaller canteen for the design engineers. But then down here there's also what they call the chill-out area, which is a bit of a darker area with comfy chairs where you can go and chill out basically. There's classical music, chill-out music playing all the time and the lighting's dimmer so you haven't got the bright lighting all the time. So there's that and especially with the weather we've been having, they've bought tables and chairs and there's a little patio area right out the front for people to go out and sit on. So they're very conscious of getting that right, and they're organising walks and rides and I think at some point we've got someone coming in to do our cholesterol levels and blood pressure and things like that so they're doing a lot of things like that. Big bone of contention over in the facility because it's not happening over there, but they wanted to trial it and see how it worked and then they're going to take it over. The other nice thing is that here there are free vend hot drinks machines everywhere, but here because people don't like to use the vending machines they provide tea and coffee and for the healthy option they provide herbal tea free as well. Facilities is going to be harder to do because there's so many people to keep happy and being a shopfloor environment it's a bit more difficult....

A2 Environmental impact & Sustainability questions (14 – 20)

Researcher On as scale of 0 to 10, how environmentally friendly would you say (company D) was?

Respondent B Compared to other companies I've worked for and other companies in the local area – i'd say probably 8.

Researcher (1hour) Is that a measure of the amount of effort company D are putting into it, and the amount of interest from management, or the nature of the operations, or a bit of both?

Respondent B I'd say it's based on management or corporate commitment really, which has filtered through to senior management and right down to assembly. There's much more interest these days than there was even 10 years ago.

> Question 14 - How sustainable / environmentally friendly would you say your company is? Say on a scale of 0 - 10, with 0 being totally "unfriendly", and 10 being perfect?
>
> Company B response summarised by researcher – 8 – based on the level of interest and commitment and comparison to others.

Researcher So what would you say are the main impacts you have here?

Respondent B The way we measure it, we've probably got about 15 main impacts that we measure and report, and there's 3 main ones – energy consumption, plastic recovery (regrind) from the waste stream, and reduction of powder from the powder coating facility. There's a couple of others that we could use that are sort of bubbling away just under the surface, and the plan is that one of those drops below the threshold and we raise one of the others up and start working on that. The big ones in the background would be scrap metal and segregation, paper and cardboard recycling, waste segregation program, and i'd say returnable packaging.

Researcher So how did you work out your main impacts?

Respondent B They're on a scale of measurement so we have a set program where we take into account the legal requirements first and foremost, then mainly the size of it, the frequency, the quantity of the product that's held on site or being processed, or it could be customer driven. We have a 12 point measurement of each of those sections looking at increase or decrease in business – it doesn't have to increase, it may decrease, for example the bigger you are, the more efficient you become, so you use less energy up, per part that you produce, for instance. We take that all into consideration. Same with chemicals or other products being held on site - say we've got 500 litres of a product in stock, do we need 500 litres? If we use 25 litres, could we get a replenishment of stock the next day for instance? That's how we've continually driven down those quantities of stock. To give you an idea we've got 2 chemical bunded containers. When I first came to the company in 2001, half of it was used for new products and the half of it for empty returnable waste products. Now we could use half of one really, just by managing the amount of products being held on site, just by contacting suppliers and saying can you get to us in x amount of time. And that's linked quite closely with the Lean philosophy too, because it's all about kanban type stock rotation. Although we haven't got the chemicals on a kanban, that's the philosophy we use.

I've been involved in the environmental bit for quite some time now, but when we have the ISO 14000 boards here – we've had 3 since I've been here (at Company D) they say it's quite a unique we're looking at, the way our environmental management system is working. And I've just done a qualification in Environmental Management, and that was an NVQ level 4 through the ILM and I was talking to their external verifiers there, and they're actually saying that it's quite a unique way of looking at it, so much so that they've actually taken some of the systems away and they're saying it's probably a better way of getting to a more sustainable process.

Question 15 - What do you think are the main effects of your operations on the environment? What about social impacts? Question 16 - How did you work out what your main impacts are and decide what improvements to make?

Company B response summarised by researcher – They measure 15 impacts, which shows the three major ones are energy consumption, plastic waste, powder from powder coating. Other larger impacts - scrap metal, paper and cardboard and packaging. They base this assessment on legal requirements, size, frequency and severity of impacts, and customer requirements. Regarding social sustainability, they are doing lots on site for "work life balance" e.g. massages, chill out zone, walks and bike rides... only in office areas rather than production as yet though.

Researcher What other things are you doing to reduce impacts?

Respondent B The idea is we're trying to reduce the usage, for the same number of parts, of materials coming in - for example virgin plastic.

Water usage, we've got a program with the environmental champions that they're reviewing that. The water board were actually sending us bills every 12 months with a load of estimates and a couple of accurate meter readings. And the way it worked before was it was just accepted and never ever questioned, the procurement guy would have a bit of a banter and then agree an invoice. Now, the environmental champions are trained to take meter readings so we're now getting a reading every month and a bill every month. And we've realised that one of the reasons why the water bill's probably not been as accurate as we think is that the water meter is about a meter and a half down below a manhole cover and it's very very difficult to read. So if we're finding it difficult to read, and we're committed to reading it, then the guy who's taking the reading's not going to read it. So we've actually asked them whether they can review it and actually bring it higher up because it would help them and help us. Another thing is that we get charged for water from the meter and we also get charged for water going out. Because theoretically all the water that comes into the facility gets used and then goes back into the drainage system. But actually we've got a pond on site, which we do top up from time to time, so some of the water actually stays here. Some will evaporate but the majority of it stays here. So theoretically there's a reduction we can have based on that. But it's never been considered in the past, we've always taken a hit for that – it's not a significant amount of money but we feel that if we can demonstrate that we're managing that water we should get a discount. (1 hour 10 mins)

Another thing is that we're looking at how we're controlling and managing topping up the water we use for cooling the injection moulding tools, and trying to reduce condensation.

Researcher Do you actually measure the amounts of water used at different places around the plant?

Respondent B We've only just started this project with the champions – we started it because two of the champions wanted to take a much more active role in actually controlling some kind of reduction.

We do manage and control our electricity for instance, we have probes all round the facility so we know where that's going and which are the high points for that we have made significant changes in the way that we carry out certain processes that've reduced the electricity use quite considerably. It's difficult to measure the effect because the price of energy's gone up what 50-60% in the last 12 months and our production's gone up about 20% in the last 12 months so even with those changes our bill on a pro rata basis hasn't gone up at all – so we've increased production by about 20% but we've used about the same amount of energy. And the way we've done that is by taking out certain high energy processes and using external contractors.

One for instance was the burn off ovens for the powder coating which is a process where we spray the parts – it's an electrostatic process... and the parts go through an oven to harden, but the racks get covered in paint too and eventually that has to be burnt off. We had our own burn-off oven here but it was really inefficient but it was also causing a problem because when they came out they had a residue of dust on them so when we put parts on them, the dust was falling on the parts which caused quality problems, so it was increasing wastage and it was requiring even more energy usage to finish those products. So we looked at a two pronged attack – first of all how can we avoid those quality problems so we don't have to coat them more than twice, we didn't have so much fat in the system. And secondly, can we find a company that burn of racks externally? And we did find a local company that do burn off racks for other companies. And they were only running at about 30% capacity, so we put our racks in their ovens. They were happy because they were running at 70% capacity, and we shared in the saving – and we took out the burn problem completely.

Question 17 - What (if anything) are you doing to reduce your impact?

Company B response summarised by researcher – They segregate and sell waste for recycling, and reuse waste (e.g. for purging moulding machines). Following a rationalisation project with customer liaison, they have been able to reduce the number of types of plastic they use and facilitate the sale of waste plastic. They design products to enable waste segregation, reuse and long life. They have reduced the amounts of hazardous products on site (JIT), reduced usage of plastic, powder (for powder coating), water and energy per unit part. They have reduced energy use for lighting. They have a smaller compressor that they use when demand is low to save energy, have fitted an air leak detector and also want to block off air runs when they are not in use.

Researcher Do you think the perception is that environmental improvement is a cost or an opportunity for the company?

Respondent B I think it's been recognised in the last two or three years that there is a cost. All the companies that I've worked for before, they see that the financial input to get things started isn't justified by the savings. But if we'd done some of the energy saving projects we're looking at 12 months ago, before we knew that energy was going to go up by 50% in the next 12 months – we'd have made significant financial savings. What we have done is recognised what we should have done 12 months ago and started to get on with it, because we know there's going to be another increase in the next 12 months. There's much more commitment at senior management level if you can demonstrate a financial benefit. It's much easier if you can talk to the senior financial guy and say we want to do this project and there're going to be these savings, rather than I want to do this project because it's the right thing to do. Not so easy to get those sort of projects through. There is the commitment there, but it's fairly low down their list of priorities.

Question 19 - Is environmental improvement a cost or an opportunity to your company?

Company B response summarised by researcher – There is recognition of costs and benefits – it is easier to get approval for projects with demonstrable benefits.

Researcher Any implementation paths you've used, like 14001 or …

Respondent B Yeah we've got 14001, we've had that since 2001

Researcher Have you had anyone like Envirowise or Natural Step or Carbon Trust?

Respondent B Yeah we're members of the Carbon Trust and we've had those through – also we host the waste resource efficiency club here, for (their county). Also I'm going through a program with Envirowise – we had an audit and I'm going to help them out – a lady's coming down who's doing a project with another company that wants to share in some of the ideas we've got here to do with medium to high level training best practice.

Question 20 - Have you followed any environmental or sustainability improvement implementation paths e.g. ISO 14001, EMS, natural step?

Company B response summarised by researcher – ISO14001 since 2001, they host a waste and resource efficiency club, have been advised by the Carbon Trust, have had an audit by Envirowise audit and mentor and advise on best practice for Envirowise as well.

Researcher Anything to add?

Respondent B One of the significant savings we've made in the past was in 2000 we were paying £140 twice weekly for landfilling plastic sprues and so on. Now we actually get £100 a ton for those, so not only do we not put them into landfill we actually regrind and use a lot of that product ourselves. And we can actually make £100 a ton of those. And that's something that can be sustainable. There's a lot more to do with that. At the moment we separate it and send it to a company who regrind it and sell it on, we're not actually using it in our products. But there's one product we use, a polypropylene, which we're actually producing about 2 tons of waste a year but we're buying 4 tons a year to purge our machines – so all we've got to do is regranulate the waste and use it for that. And that's a program we're going through at the moment, we've got our own regranulator machines but they're not working as effectively as they should at the moment.

I think one of the most difficult things for companies is to have an incentive for individuals that encourages them to do something. It's great to have an idea, but if it's going to mean more work, or more hassle and more criticism for not doing it, then they're not going to do it. I think there need to be much better financial recognition through the appraisal system for them doing it. And I'm actually in a meeting with our benefits and pensions manager here looking at exactly that, I've got some plans for how we could plot that out, so people get recognition and it'll affect their personal bonus. Just by being involved with that and ensuring the sustainability of some of our programs. Because not every program works. Some of the things we've put in, if they all worked it'd be great. But some of them don't - you think you're going to get some quite big benefits out of them but you realise things aren't the same as you hoped. But hopefully you learn from those mistakes and try something else.

Researcher With CI do people get benefits?

Respondent B Yes, what we've started to do with the CI is if a project is sustained, the team that implemented it get - we pay for a meal or a skittles night or something – (1h20min)

Respondent A but it's looking at the sustaining part not just completing it.

Respondent B The idea is, especially with the plastic regrind, it's great to get that money back, but the idea is designing moulds that produce less or no waste – for example the mouldflow tools, if we introduce those 100% in our factory then there is no waste stream – so you're not producing it in the first place, that's the key. But we have some waste streams – we're getting the engineers now to make sure they're no more than 10% of the product weight, but we have some waste streams here that are twice the product weight. And that's purely because of the design of the tools. The mouldflow tools produce no waste and use less energy, but they do have high maintenance costs. Now customers – I was trying to reduce the amount of different plastics we use because if each customer has their own special little bit of plastic you're not going to produce quantities of waste that anyone's going to want. So you end up paying for it. So I'm trying to get the engineers to use only the top 12 plastics in the world. So the benefit of that is that we have a massive slump in Europe and a large amount in the States we can send it over there, knowing it can be made. Because the problem is if you've got customers specialising in their own little plastic that's almost insignificantly different to another plastic, you're really putting yourself against the wall, because when that disappears, what's going to happen? You've got a huge amount of work, maybe FMEAs, to redesign that product and make sure it's viable, when the chances are you could have made it from one of those 12 plastics in the first place. I'm saying to the engineers that we've got to be much more smart when we're talking to our customers – I mean we're supposed to be the experts, why don't we talk to the customers and tell them to use a plastic that's already on the market?

Researcher You have access to the engineers to say that kind of thing?

Respondent A Oh yes. It's easier now isn't it, now the design engineers are here and everything.

Respondent B Oh yeah. I think there's been too much bending over backwards for customers without any question, if you want that plastic use it, "the customer is king" and all that. But I think it would be a benefit to themselves – I mean if we were to say to them we've got a plastic here, if you used it, let's share in the benefit –they'd welcome it with open arms but because I don't think they're having that conversation often enough, they're saying this particular plastic is the best thing since sliced bread and it's well let's use it then, it's just adding another supplier on our register. So you've got all this control elements too.

Researcher That's a huge tie in with Lean isn't it?

Respondent B Yes. Other things that are really coming into play now more and more, are the way we're actually designing it – I think in 5 years time we'll be buying cars with second hand parts in. Because our (products) are designed to work for 20 year, and they're also designed to be disassembled without any damage to the internal parts. So we could dismantle them – take the (component) off, fit a new (component) and use the internal mechanisms. Why not? We're already using regrind materials, although some customers are saying they don't want to use regrind material because of quality issues. But I think quality in plastics is getting much much better, although so is the range and number of plastics unfortunately! But I'm convinced that soon we're going to be using second-hand parts.

There's a lot of things that could be used in cars – I mean in seats the fabric might wear but the springs and the mechanisms etc. particularly the passengers seats, I mean the drivers seat might take more of a pounding than the others. But if you could find a way to design it so you could take the covers off, the internal mechanisms, the expensive bit, might be perfectly sound.

A3 Sustainability and Lean questions (21-23)

Researcher How much does the Lean and sustainability stuff work together at the moment?

Respondent B <u>Well we do the CI stuff, I mean we're just doing a big project at the moment on electricity saving, that's acting on some of the suggestions</u>, and the month before last we did the powder coating one, and we did regrind, we do try and look at those significant areas, and <u>all the Lean cell changes in the manufacturing areas, I'm involved not only in the health and safety aspect but there are also environmental issues there.</u> I mean one of my biggest bugbears at the moment is one of our products is a panel that has a plastic film put on top of it to prevent scratching and the one issue is the amount of damage that's still caused, that leads to wastage, but the other thing is that when the parts come out of injection moulding they're still hot, and when the film's put on it bubbles up. So they needed to cool the parts down and they decided the cheapest way to do it was to blow an air stream across. Well one it's too noisy, and secondly manufacturing air is phenomenally expensive. And what they should have done is investigate the many cheaper ways of cooling it down..

Respondent A (For example) They could've dunked it in cold water...

Respondent B Yeah, it's just crazy, it's so wasteful, they could've done loads of different things. Because it's constantly blowing across there... I actually measured it, and in a five minute period of air going across there, the (components) were only on there for a 25 second period out of those five minutes, so the rest of the time it's just cooling nothing. There's no sensor to tell it when to blow – that's not Lean and it's certainly not environmentally right.

Respondent A I never knew that....

Researcher So you two weren't involved in design of that?

Respondent B No – what it was, we didn't know the film was going to bubble up – when they tested it, it wasn't done right next to the injection moulding machines, and the parts had had chance to cool, and they didn't allow for the fact they would be coming straight off the machine and would still be hot. But the bubbling up causes a big problem in assembly with the bowl feed machines, it's got to lie flat. So they had to work out what they were going to do. So they've got this little robot thing that drops down on an arm and the air stream blows across it.

Researcher (1h 30) What sustainability benefits do you think you get from the standard Lean implementation?

Respondent B I don't know across the board, and the sustainability thing is relatively new here, but environmentally I would say that the plastic one is probably the worst one we've had, and that's probably the one that's had the most work on it. Although we've had some good financial savings, because the processes we've put in place are quite time consuming and difficult for the operators to put in place as part of their normal standard work, so I'd say as far as sustainability goes, we're about 30% of the way there – we're getting the savings in plastic but what we're not doing is taking things further by the new projects coming up, designing the tools so they actually have less sprue waste, or using mouldflow which have no waste, which takes out the need to have regranulators and so on because you won't need it, if you have no waste.

I'm a great believer, especially in environmental issues, that you can't go from producing 45 tons of sprue waste a year to changing all your tools to mouldflow not producing any waste – there has to be a learning curve – what do we do in the meantime, let's not just wait for mouldflow because chances are we'll probably never get to 100% mouldflow in this factory, given that some of the mouldflow tools cost around £1million for design and manufacture, so therefore we try to control the process – we try to segregate the waste material, we've now colour coded it so that's improved it a bit more. The next thing is to reducing variation, we currently granulate the top three materials we've got, so we need to try and extend that and extend the idea of producing more of our high-volume products from the same material and granulate them ourselves on site, we can actually get about £130 a ton if we granulate them ourselves, so that can be quite significant on a long run particularly. So you've got less bags being used, less pallets being put on and less manpower – it's not just the material it's the fringe stuff as well. And that's not always easy to get a measure of. Because the chances are that one of those processes along the way will be more difficult compared to before so you need to get a balance, a compromise.

Researcher What about energy reduction in standard Lean?

Respondent B We've got a lot of projects under way. We've actually replaced 90% of the lights in the factory with much more economical lighting, because we discovered along the way that whoever fitted the lights in the first place fitted the wrong ones. They actually put low lights in the higher parts of the factory and vice versa. So we've changed all those lights but the trouble is now that we've got banks and banks of lights so the next thing we're going to do is we're looking at grants from the carbon trust for closing those down in banks. And the other thing is that we do have some customer specifications that make it more difficult, for example the general light level in the factory is probably about 500 lux, but we have some areas where customers specify it must be 1000 lux for inspection. So as well as the general lighting we also have localised lighting above some of the assembly areas purely for inspection. And over the last 18 months I've also had fans fitted to some of the fixtures as a mandatory requirement. And of course they're all using energy, but we try and look after employees and have them working in a more comfortable environment. So there are some compromises to that but we expect to start making some savings once we get the lights above, specially on night shifts and weekends. We also have two big compressors that run 24/7 but we've also purchased a smaller compressor from the company we bought, we're going to cut that into the system and that will run on evenings and weekends, rather than supplying enough air for the whole factory when part of it's shut down, that's going to reduce the energy use we think by about 60% on Saturdays and Sundays, because it's very expensive to produce air. And there's a lot more we can do, for example we can start blocking off air runs to different parts of the factory, when they're not being run, night shift particularly we don't need a big supply. So for example in the area where we've got the air stream working, they're still being worked when the factory's not working. So it's like the lighting, we need to start looking at ways of putting those in banks. We've still got a little way to go on that, but there's no reason why we can't start doing that. Within our master cell plan for the kaizen events, we could have a cell master switch so if the cell is not being used to make products, you can just shut it down, we just put in a bypass to still feed other cells that are running.

We do sonic testing at all our TPM and kaizen events now, to detect air leaks throughout the plant. We do that every time we do a design change because there might be air leaks that you can't hear.

Question 21 - As a result of your lean implementation, did you observe any of the following…. Reduction in energy usage, reduction in waste, increase in sale / reuse of waste, ….

Company B response summarised by researcher – They have seen a reduction in material usage, but not as much as they would like – there are ideas for more projects. Have done CI projects for energy usage, and waste material reprocessing in-house. Some lean projects have equal benefit financially and environmentally – the environment officer (respondent B) is involved in all projects in his health and safety capacity and so is in a good position to assess this.

Researcher Are there any ways the Lean projects have made things less sustainable or less environmentally friendly?

Respondent B I think mainly electricity use – when they move cells around (lighting no longer designed to suit cells and lose localise lighting)

Respondent A – when we moved the cells around we didn't even consider the lighting so a lot of the benches had to have localised lighting put in.

Respondent B – yes and that's never allowed for in the cost of the Lean itself, it comes under the umbrella of health and safety usually.

(1h40)We have one or two main companies that supply the benches and we've worked on ways to get good lighting levels, up to 1000 lux, with minimal extra lights – but I think we've got a long way to go although they are much better than they were but we'll learn as we go along. I think in the long term in winter on nights and weekends we'll have enough localised lighting that we'll be able to shut down whole banks of those overhead lights and the lighting levels will actually improve, because there's a lot of shadows cast – there's disadvantages of using those overhead lights sometimes. So in the long term it'll actually improve. But you've still got to move between cells, so what do you do there? We have got movement sensors in some of the offices, to try and save a bit of energy in that respect. We should be able to do more of that with the Carbon Trust funding that's available – well it's not funding exactly…

> Question 22 - As a result of your lean implementation, did you observe any of the following…. Increase in energy usage (on site), increase in transport miles, ….. Anything else that you feel made your company less sustainable / environmentally friendly?
>
> Company B response summarised by researcher – Changing factory or cell layouts increases the need for localised lighting, because the main lighting is optimised for the old layouts.

Respondent A We should put those sensors in the toilets.

Respondent B We've actually got those things that help us with the flush levels, we've got sensors in the men's urinals so they don't flush at all unless there's someone in there that's picked up on the motion sensor. Usually they work on a solenoid valve so they flush every half an hour or something.

In the states they've got hand flushes but here they normally do it automatically, but ours have got a little sensor on so it doesn't work at all until someone's standing in front of it – it picks up your movement and then flushes.

Respondent A They have automated flushes on the ladies toilets too. You sit down and then when you stand up, it goes...

Respondent B Out there, particularly on the urinals it's a measured flush, it doesn't need as much as the pan types.

I've just done the calculation for our water bill and ours is – I think it's 25 cubic metres per head is best practice I think, and ours is about 0.3% inside that. So we're really efficient for a building this size<u>. It's worth looking at that because if you've got a national average, what you should be aiming for, and you look at that front end as far as Lean is concerned, you could say to yourself well if we were using four times the national average per head for a factory this size, you'd know there were likely to be some significant savings. But we're 0.3 within it so how much time and effort are you going to use to get improvements? Very little. But without doing that calculation and looking at that you don't know.</u>

Any improvements you try to do are going to take a lot more money (for a small improvement). What you can say is well OK we're doing OK, put it on the back burner but it's a great project for new environmental champions that are coming up there, because they're looking at something that's already under control so when they start thinking about these things they're all there [Company D, Respondent A, 1h45]

Respondent A – it pushes them that bit further doesn't it?

Respondent B – That's right – and then you can actually say anything we do in the factory that's going to have an impact on water use, we need to be considering these issues now, not at the end of the job. [Company D, Respondent A, 1h45] Cos that just comes out of someone else's budget – mine usually!

Researcher Any other comments about the idea of using Lean tools and adapting them for increasing the sustainability benefits?

Respondent B - I think it's really important that we work together and learn the tools, because I think we should be in a position where we're doing them almost without thinking, it should be part of the normal consideration when we're doing improvements. When we're changing a cell or implementing a process or product line, It should form a part of the philosophy. [Company D, Respondent A, 1h46]

Respondent A – Part of the considerations for sustainability should be putting in some form of measurement – easy measurement, that can be tracked. Because that's the only way you know if you're sustaining it or not. Another thing that we do is we do regular audits and that also helps to show, but if you want to look at it on a daily basis you need to have some form of measurement in there that you can look at daily, that shows have we gone up, have we gone down, have we stayed flat, because if you don't have that, you don't know if you have improved, you don't know if you're sustaining it, and if you want to do another improvement you don't know where you're starting from. [Company D, Respondent A, 1h46]

Respondent B – yes, as a past example – to say you've got to be controlled – is the paper recycling we do. Every year we recycle 110% - 120% of the paper we buy and people say well how can that be, but it's all the junk mail and catalogues that come in. An example is the RS catalogues, there are 7 volumes and we had 18 of them coming in and all of them were getting binned. So I phoned up RS and cancelled all of them except two, one set for (catalogue items) office and one for the library I'm setting up. And not one manager called me up to say where's me books – not one, so they were obviously just going straight into the recycling. And it means a bit of a commitment from the managers to say I'm getting this stuff in every week or every month – because there's always a number on there because by law they must stop it if you ask. The way they've got round it these companies, is as soon as you put an order in from the copy in the library marked "for the attention of..." you start getting it again. So it's really important for us to keep control of it, and the easiest way to do it is to say send everything by email, that way they can just delete it. But it's still the best way for companies to get sales. So the easiest way to do it is keep it all in a library. As part of their 5S activity people have to take the catalogues to the library and we're starting to mark people down on their 5S score in offices if they've got catalogues in there at all.

Respondent A – Oooh, that's a good idea.

Question 23 - The aim of this project is to use lean tools and adapt them to increase their sustainability benefits - what are your thoughts on this idea?

It is important to work together and to know the tools. Measures as used in Lean would be an important aid to sustainability improvement.

Appendix B – Summary tables of responses to interview questions

Question 1 – What instigated your initial interest in implementing lean?

A	Mainly a way to improve customer service (lead time and on-time delivery) (quality cost effective product delivered on time – customer service underpins everything else) - cost saving (driver for parent company) - Structured improvement process - Stock & WIP reduction - Being in control of processes - longevity (changes become way of life) - Quality improvement - Meeting needs of customers, shareholders & internal needs
B	Their lead times had increased, so they could not produce enough product, and benchmarking (with consultants) suggested that lean/waste reduction would release capacity. A new MD recognised the potential of Lean.
C	The company was near bankruptcy; respondent A was recruited as MD and had previous experience of Lean.
D	A new CEO was appointed who had experience of Lean. The company wanted to move into new markets, and had made acquisitions, where Lean was prevalent.
E	Decline of their market share and sector meant they needed to maintain same level of service at lower cost to maintain competitiveness and diversification.
F	Cost of their products was becoming uncompetitive
G	A subsidiary of their IT sub-contractor came in to help with improving processes and making savings etc. They had a good product, market acceptance and a growing market share, but the profit percentage was too low because costs were too high. Had already gone through equivalent improvements in design processes to gated processes etc., so applied same logic to process improvements.

H	cash! But making smart changes not just pushing people to work harder to be more cost effective.
I	Saw lean as a tool to help achieve their productivity improvement target, reduce costs and improve productivity all of which are necessary in order to survive. Respondent A and his manager completed a training course with a Lean element. A drive to improve rather than to survive a crisis.
J	They wanted to improve through value chain and looking at supplier base and customers using lean. Competitors looking at lean and need to stay ahead (ahead on technology but a bit behind on Lean).

Summary – Most often there was a new CEO or similar to champion Lean, and/or a desire to improve and stay or get ahead of competitors, and/or a desire to make cost reductions and productivity and efficiency improvements. There was also some influence from customers or subsidiary companies. Only one company reported an absolute crisis of imminent bankruptcy.

Question 2 – When did you start your Lean implementation?

A	First started ten years ago (using some tools but fairly unstructured). Began in earnest 4 years ago.
B	1 year ago launched (CSPS) - started pilotting CSPS 9 months ago (rebranded) and have just started third kaizen blitz event. Several unsuccessful incarnations of Lean or "kaizen" previously.
C	Two years
D	3 and a half years ago at that site
E	About 15 years ago – they were one of the earliest adopters in the UK.
F	Operating to best practise for 5 years.
G	Began the precursor to Lean 10 years ago.
H	Began Lean thinking about 5 years ago, although it has not been disseminated to all staff and areas.
I	CI for 6 years, Lean at that site for 2 years but implemnting some Lean tools for a year before that.
J	1 year ago, but were using some tools a year before that.

Summary - Most had a phased start or had several attempts or incarnations. Varies from company E who started before the phrase "Lean" was coined (early 90s) to company B who piloted their CSPS 9 months ago. Maturity does not necessarily follow the trend of time since starting. It is notable from the responses that companies often have a number of attempts at Lean in their past, before settling on a style of implementation that works for them.

Question 3 - Was your expert in-house or consultant?

A	They used a consultant at first (for about 8 months). They chose their consultant based on a customer recommendation
B	The parent company used a consultant whose methodology was not a good fit at company B - tendency towards making changes rather than teaching clients to make changes. Company B used respondent A who was then hired as the OM. There are internal consultants within the parent company (involved in developing the CSPS) who also work at company B.
C	Used a consultant.
D	Started off with consultants and still use them, but now they have more in-house expertise (they have also hired staff at all levels with Lean knowledge) staff learn by reading, they learn from other companies and attend seminar days.
E	They hired a Lean expert initially and also deliberately acquired customers with good Lean knowledge who trained their suppliers. They used a consultant once a month for 3 or 4 years. They are now consultants themselves. They find that some consultants are very good and others aren't, even within the same company.
F	Sent a couple of engineers for training, used UK enterprise visits, read a lot but didn't use consultants. Looked at a lot of case studies. Consultants often "take your watch to tell you the time".
G	They have used many consultants - but often not that helpful (borrow your watch, tell you the time, then walk off with your watch) although give outside view - if you don't do this what are you going to do? Difficult to say "the same as before" when consultants are paid for and have been authorised from high up in company. Have credibility that internal teams don't, although they may not actually be more credible.
H	They send some engineers and managers on training courses. They will use consultants who do interesting things with people on the shopfloor and have a hands on approach, but avoid those who don't - paying someone a lot to tell you things you don't really need to know and not doing anything practically is counter-lean as well.

I	They used a consultant to initiate Lean but now are working on their own to consolidate that work.
J	They recruited respondent A, who had experience of Lean and continued to train at a university. They also learn by visiting other companies, networking, etc.

Summary – Many companies gained help from consultants initially but were sceptical about how much help they were. Popular ways to gain knowledge were to hire new staff, learn from other companies, train existing staff or for existing staff to learn from books.

Question 4 - Did you use a recognised lean implementation plan, or choose the tools that fitted your needs best?

A	Choose the tools that fit best - do Value Stream Mapping (VSM) now, which helps to shape activities, but didn't at the start although they now realise this would have helped. Have never particularly assessed customer value.
B	Their CSPS is a fairly honest copy of the Toyota production system "why would we want to change it significantly". Management systems, visual control, people, teamwork, CI, voice of customer are very important as well as the tools and techniques.
C	Used their consultants' plan
D	They begin with 5S, then work on setup reduction and flow; VSM drives from there. Their consultant sets objectives for the year.
E	Used a consultant's plan - but now have a CSPS, which has developed over the years as ideas on lean have changed.
F	They have used a mix of things, whatever suited at the time. Philosophically would probably align most with 6 sigma, but have also used "The Rope", Deming. They use recognised training for root cause analysis which is predominantly work-based exercises, learning by doing - which is important to them.
G	They have tried most things! Keen on Kaizen workshops for a while, have now developed a CSPS.
H	They adopt tools as and when they feel it's appropriate.
I	Their structure is based on a consultant's - VSM guided implementation but the first thing was to do training and awareness and to set up lean steering team.
J	Tried direct from the book, but the terminology caused problems (level was too high) - acceptance varies from site to site - learning point was that you need to adapt to your people.

Summary – Most had some kind of structure although this tended to have evolved over time. It was often based on a consultant's structure if they used a consultant initially. Some companies have gone as far as to develop a CSPS which is generally their own adaptation of the Toyota Production System (TPS). Several use value stream mapping (VSM) as the backbone of their implementation structure.

Question 5 - Please can you briefly describe the structure of your lean implementation?

A	Used 1 line as a pilot then rolled out from there, applying tools as needed throughout the factory. CI drives everything.
B	Kaizen blitz structure. Gather data, identify problems, do preliminary 5S and safety improvements, then implement solutions to other identified problems using Lean tools, Sustain. Customer value isn't currently tied into lean but working on integrating lean more closely with design and sales.
C	A series of kaizen-blitz events - guided by VSM and metrics, aim is to reduce lead time and inventory etc. They assess which products have long lead times, or where there are business opportunities and run blitz events there. Then measure as many things as they can think of, and do a VSM to identify bottlenecks, and go from there.
D	Did 5s first, including standard work and visual management. VSM drives kaizen etc. 5S showed up a lot of the low hanging fruit and already knew some areas that they needed to improve. Value streams pre-existed. Then looked at flow and product families and layout of factory. They use kaizen blitz events. Year on year, the implementation is driven by the year's goals suggested by their consultant.
E	They have a CSPS, a philosophy of working underpinned by a set of tools and techniques. Key components are process mapping, problem solving, standard work and auditing. They've now started doing six sigma alongside lean, to deepen awareness and gather data.
F	They ran workshops for nearly all staff, and kaizen events in areas where they observed problems, concentrating on elimination of waste - wasted labour, materials, floor space - designed lines for ease of reconfiguration to follow varying volumes. They use blueprints, current and future state process maps, and break down into actions to achieve the future state, KPIs etc. The last two years they have begun to focus on the supply chain outside the factory, predominantly their purchasing procedures.

G	They have a CSPS based on "how to"s (rather than tools) e.g. how to operate machinery, or design work areas - and picked up some tools along the way. They also do a lot of direct problem solving on more complex problems e.g. process capability, lead times, quality issues etc. – they have now realised that they are capable of solving problems or can bring in expertise when they need to. "Today we're driven directly by issues facing the company."
H	They have so far worked on knowledge management, factory layout and cellular manufacturing. They have done some SMED but need to do some more, and the next thing will be kanbanning, got some vendor managed stock. Some more things to do but not done yet due to time issues.
I	They did factory –wide training and awareness first, then simple kaizen-blitz type workshops in defined areas. They used value stream mapping of key process, to demonstrate the amount of room for improvement (value added percent was 0.03%? which showed people that this was an exercise worth doing), and current and future state mapping.
J	Form a team, have an icebreaker event, introduce a game, introduce and teach lean practices, then go into shopfloor. Teams are drawn from several dept.s choose a project to work on. Have lots of teams working on particular problems the team leaders have generated - Redesign of forklift loadguard (by the driver), energy saving (fluorosave for lighting), grading stock to get weight correct. Standard templates for presentations based on DMAIC, have a presentation day. Back up with altered SOPs once project is completed (identified need for SOPs). Need to be careful about expectations, taking on too much improvement work.

Summary – Responses varied a great deal. Kaizen blitz or kaikaku i.e. intensive work to bring one area up to scratch, is quite popular, and may be aimed at known trouble spots, areas where opportunities have been identified, or where VSM had indicated a problem (this might work well as a basis for a tool as it's easily focussed and managed). Blueprints or visions, current and future state mapping are also popular. What most have in common is that Lean provides them with a structured and rational way of making improvements. Most have a dedicated "Lean team" that usually works with operators etc. in areas - the Lean team facilitates the implementation.

Question 6 - Which lean tools do you use?

	A	B	C	D	E	F	G	H	I	J	
5S	x	x	x	x	x	x	x	x	x	x	10
Kaizen (Continuous Improvement)	x	x	x	x	x	x	x	x	x	x	10
Poka-yoke	x	x	x	x	x	x	x	x	x	x	10
Value stream mapping	x	x	x	x	x	x	x	x	x	x	10
Pull systems	x	x	x	x	x	x		x	x	x	9
Root cause analysis (five whys)		x	x	x	x	x	x	x	x	x	9
Single piece flow	x	x	x	x	x	x	x	x	x		9
TPM	x	x	x	x	x		x	x	x	x	9
Value / muda		x	x	x	x	x	x	x	x	x	9
Takt time	x	x	x	x	x	x	x		x	x	9
Visual control	x	x	x	x	x		x		x	x	8
Kanban	x	x		x	x	x		x	x	x	8
Cellular manufacturing	x		x	x	x	x	x	x	x		8
Kaikaku / Kaizen blitz		x	x	x	x	x	x	x	x		8
JIT		x	x		x	x		x	x	x	7
SMED (Single-minute exchange of dies)		x	x	x	x			x	x	x	7
Smoothing		x	x		x	x	x	x	x		7
Two-bin	x	x			x	x	x	x	x		7
Milk run		x		x	x	x		x	x	x	7
Heijunka (levelling)		x	x		x	x	x				5
Rightsizing	x		x		x	x		x			5
6 sigma							x		x		2
6 sigma express / 8D	x	x									2
Communication cells					x				x		2
Goal setting / deployment	x			x							2

Question 7 - What were the financial benefits you observed? Question 8 - How do you measure the financial benefits? Question 9 - Can you identify why they occurred, and at what stage?

A	Planning and forecasting are more accurate. Productivity, head count, WIP and stock reduction and lead times all better. They have doubled the output from the same factory space and without doubling e.g. electricity use. Company goals filter all the way through the organisation. They have workplace audits and KPIs.
B	40% internal quality improvement (ppm rather than right first time), 35% improvement in external (as del) quality, 50% improvement in productivity on first and second blitz event, 40% reduction in cost per unit. Benefits are spread evenly throughout blitz events and sustain stage. Measure things to change behaviour – there is concern that measures/targets may give incentives for "wrong" behaviour. They measure everything, possibly too much. .
C	Representative B had a presentation of financial benefits (confidential) which they had measured. They were able to charge more for reduced lead time supply, having identified the minimum lead time using a VSM exercise. Benefits are mostly as a result of blitz events. They set measures at initial meetings to plan blitz events, and gather data before and after blitz.
D	They quadrupled turnover in the last 3 years - globally aimed to triple after 5 years, achieved in 4. They report weekly and monthly on various KPIs, some of which relate to financial effects.
E	They expect year on year to make savings based on implementation. They predict that they would not still be in business had they not implemented. They can calculate significant financial savings from projects within implementation, often making savings by redeploying people. All Kaizen events have goals of saving space, time, money etc. Tthey use workplace auditing to ensure continued cost-saving.
F	Predominantly from decreasing stock levels and WIP, also have lost some people. Implementing one piece flow will lead to 67% reduction in manufacturing space (thus avoiding the need to aquire new

	premises), 45% reduction in manufacturing time, increase capacity and reduce walking by 75%. Benefits are mainly from major projects, and they have KPIs that relate to cost savings and must be reported.
G	Approach has been too scatter gun to really observe any benefits and it's hard to say what would have happened if they hadn't implemented, but they're pretty sure they would be very much smaller or not here at all. Can show costs of some individual products have gone down, cost of quality gone down. They are concerned about the effects of other variables – they tried measuring inventory but found it too dependent on production figures. Also, they can't tell what things would have been like if they hadn't changed.
H	20% more production with 80 people rather than 120, additional cost elimination - scrap reduction, minimising cost per product. They attribute most of the financial benefits to factory reorganisation. Financial effects are part of their normal measures.
I	They made savings by reducing floorspace requirement (including reduction of stock held, which lead to a reduction in requirement for warehouse space) and improving layout. They categorise lean savings including CI team savings and can attribute financial savings. Doing more with same number of people
J	They have made significant savings and can attribute cost savings to projects and improvements. Savings have been made by changing methods of waste disposal, waste reduction, energy saving, standardisation of best practices and reducing water usage (by both leak spotting and buying efficiency equipment). All inputs are costed per tonne of product throughput, they have standard regular measures and measure the effects of improvement projects. Pre-project state measurement & projected benefit are standard parts of projects.

Summary – most companies have made significant financial savings and can quantify them, and most have KPIs for projects and/or carry out workplace audits regularly. Meaningful measurement can be difficult as you don't know what would have happened without the changes is mentioned. Financial benefits are gained from a range of sources, including major improvement projects, blitz events, floorspace reduction, headcount reduction, and overall efficiency improvements.

Question 10 - What other changes did you observe - more in the way that you run your operation, in your processes and procedures, that kind of thing?

A	Balancing lines has made a big difference and is very visible
B	They have observed a “can do” attitude among staff, and a recognition that there are different ways of doing things and seeking them out.
C	They've introduced new technologies and identified others but not adopted many yet (usually because of cost issues). The way they go about procurement of new machines has been altered by lean too.
D	Altered layout is the biggest visual change, communication of company metrics was a big change and so was visual management. 5S was a big change for people, and in general they observed a major cultural change. Some terminology adoption.
E	More visual, fewer non-value-added steps, more challenge from shopfloor workers about why they do what they do, understanding how what they are doing fits in with the bigger picture
F	Supply chain and purchasing look much different. Physical layout and (predominantly) the amounts of material held, look very different on the shopfloor.
G	The main change they have observed is staff awareness of Lean and understanding why they're doing it rather than doing it by rote, and the rate of change (products, people, projects, building new factories).
H	The main changes are layout changes and a product rather than process focus. SMED efforts cut changeover times in key processes from half a day to an hour in some processes, and even down to 15 minutes in some cases.
I	Change of layout has been the major change.
J	People's attitudes and understanding have changed, they ask more questions and look for ideas and do more things on their own (e.g. putting tools on the line/design their own workstations) and driving 5S. They have made some layout changes. Bins have moved and

	waste segregation happens now (because of lean or leg?)

Summary – most commonly reported changes are physical changes in layout and changes in the understanding and attitude of staff, and empowerment of the workforce to make changes.

Question 11 - Do you see lean as a one-off project, or something you will continue to do for the foreseeable future?

A	Lean is a way of life.
B	Lean is a paradigm shift and away of life, not a series of projects.
C	Lean is a way of life and is used throughout the organisation, not just shopfloor.
D	Lean is for life - because of the culture change and to ensure improvement is sustained.
E	Lean is fundamental. And here to stay!
F	Lean should be a way of life - but "it's like hand grenades", the OM (respondent A) has to instigate actions or business as usual continues.
G	Lean is a part of the furniture - can't imagine anyone adopting something else or someone else coming up with something radically different, and they can't stop doing it because they've got rid of space, people etc.
H	Lean is the way things have to be, long-term. The right and sensible thing to do.
I	Lean is here to stay - maybe the name will change, it's important to keep it fresh as ideas get tired and people like new ideas - maybe lean-sigma as they're doing six sigma as well as lean.
J	Lean is here to stay. They're in their infancy (with lean) but feel like it's been much more than a year that they've been doing it.

Summary – the respondents all felt Lean was "here to stay" at their company, except at company F where the respondent felt that Lean was extensively driven by him and might not continue were he not there to drive it. Respondents mentioned that the changes they had made would make it hard to revert to old ways now (for example they had changed layouts, reduced headcount and changed culturally).

Question 12 - How lean do you think your company is today - say on a scale of 1 to 10, with 10 being "perfection" and 1 being "not at all lean"

A	5/10. Strong on visual management but not yet lean all the way down their supply chain (they are currently working on supplier kanban, JIT etc.) "It looks quite good but is a long way off being truly lean"
B	It varies within the company (some areas are better than others). Being harsh, 4or 5 but they will get to 7 or 8. Compared to uk industry as a whole, they would probably score 7 now.
C	2 – they have a scale to rank themselves against which is supplied by their consultant.
D	Tentatively, 3 or 4? But they are unsure what to compare themselves to. Their value added is approaching 1%.
E	9 compared to other UK companies, they are far ahead of others in the UK. But only around 5/6/7 on the journey to perfection.
F	3?
G	4 - and further improvement gets harder exponentially.
H	3, maybe worth 4 due to awareness of what's still to do (culturally, 1 maybe? compared to companies where the tools are part of the way they think)
I	5 - in terms of true lean. They've done well so far but there's a lot still to do.
J	4 or 5? (8 or 9 in a year's time?) 30% of people are involved (team leaders up at the moment) - Higher in terms of how they've done in the time, as they've only been going a year (raises their score to 6 or 7). They don't work out % value add - but it's difficult with their product as the environment determines a lot.

Summary – there is quite a wide range of scores - between 2 and 9 - and ways of assessing what the score should be. Some respondents appeared to be more generous than others. Some made the distinction between comparing to other UK companies and % of perfection they had achieved. Some had a comparison scale (e.g. from events attended run by consultants), some made some kind of estimate of their progress towards Lean perfection and some quoted % value added times. Average seems to be around 4 in absolute terms.

Question 13 - There appears to be no 'one truth' about what lean is. Can you say, in one sentence, what are the principles that make up lean for you?

A	Reduction of waste - all of lean goes back to this. One of many available tools for CI to drive business forward. Or a set of tools for optimising current lines and setting up new ones.
B	Tools and techniques as third, management system (visual control, support, leadership interaction with teams) second, cultural system (team organisation, allowing time for CI, measurement against CI, safety) most important.
C	Main aims are lead time reduction and inventory reduction - everything else is a sub-set of this.
D	5 main principles - understand value from the customer's perspective - being clear on the value stream - flowing the value through the value stream to the pull of the customer while seeking perfection. "Making what the customer wants when the customer wants it."
E	An all encompassing system that's trying to, as efficiently as possible, turn a raw material into something the end consumer wants. Lean is holistic, as well as being about the tools and eliminating waste – it is about developing a completely holistic business system that goes right through from strategy to shop floor and from supplier to customer, that is all-encompassing. Deeply understanding what work you have to do and aligning resources with the work - a controlled system. A balanced system, not squeezing out the most work from the least resources. Including life balance. Orientation to work. Doing things rather than talking about them.
F	Sustainable improvement of the quality of people's working life, benefit to customers and profitability of company. Make it an interesting place to work to improve customer satisfaction which therefore increases profitability. Being an easy company to do business with because of having simple streamlined processes that employees understand.

G	Highest quality, lowest cost, shortest lead-time. TPS is the only modern proven way of delivering all three.
H	Doing the right and sensible thing (in operations, manufacturing, storage…) and communicating better.
I	Delivering what the customer wants in the most efficient manner.
J	Keeping the workforce together and performing. Understanding, innovation, performance. It's about being more competitive and not about losing people but being better and more efficient at what you do, and reducing cost of product going out)

Summary – Themes within respondents' definitions of Lean were: Reduction of lead time; Understanding and optimising value to the customer; Improvement in quality; Reduction of costs; Improving the quality of working life; Optimising processes; Waste reduction; The tools (but that is less important); Reduction of inventory; Workforce involvement and culture; Understanding the value stream; A holistic system; Continuous improvement; Simple processes that are easy to understand; Doing the right and sensible things; Making at the pull of the customer; Aligning resources with work required (levelling/balancing); Doing things rather than talking about them.

Question 14 - How sustainable / environmentally friendly would you say your company is? Say on a scale of 0 - 10, with 0 being totally "unfriendly", and 10 being perfect?

A	8/10 compared to other companies, 6/10 compared to what they could be.
B	2 out of 10. Within the company there is knowledge of impacts but respondent B does not feel there is real commitment to reducing them. 10 out of 10 would be scored where environmental improvement is totally integrated into way of doing business.
C	7/10. They have a system in place to recover as much processing waste produce as possible for reuse or recycling. There are particularly stringent regulatory requirements for their environmental performance.
D	8 - high level of interest and commitment.
E	Not consistent across group. 5? They have measures – for example, waste landfilled, waste recycled, energy usage, water consumption – and set targets for reduction. They are designing a new auditing system to take them beyond compliance.
F	Respondent A - 9 – he is not aware of anyone in the UK of a similar size that's doing better. Respondent B - About 5 (for products) - huge intent and drive within the organisation. Their parent company has a dedicated team working on impact reduction.
G	2 – There is awareness of sustainability and the impact of products, but they are not very far down the road of doing a great deal about it yet. They have a number of opportunities to change that. They are not as mature in sustainability as they are in lean - environmental impacts are understood but sustainability isn't well understood.
H	3, maybe worth 4 due to awareness of what's still to do.
I	6 or 7. They are doing quite a lot of environmental projects (see below).
J	Fairly high – 7. There are some areas that they could be a lot better at, and awareness varies within the company.

Summary – respondents based rankings variously on knowledge and understanding of impacts, what has been done to reduce impacts, the commitment to reducing impacts, and how high impacts are compared to others in the sector, to UK manufacturing as a whole, or to how much they could be reduced. Some pointed out that there are inherent impacts associated with their products or barriers to impact reduction that they face. Rankings varied from 2 to 9.

Question 15 - What do you think are the main effects of your operations on the environment? What about social impacts?

Question 16 - How did you work out what your main impacts are and decide what improvements to make?

A	Scrap, energy usage and packaging – they estimate these to be their main impacts.
B	Climate change - effect of iron and steel production, and they use a lot of electricity. LCA would show CO_2 in their products' use phase as major though. They have done some quantitative assessment of their impacts - but not using LCA fully.
C	Regulations require them to assess and minimise their environmental impacts (no comment as to what the major ones are). They assess their social impacts to be minimal as they do not receive complaints and are a major employer.
D	They measure 15 impacts, which shows the three major ones are energy consumption, plastic waste, powder from powder coating. Other larger impacts - scrap metal, paper and cardboard and packaging. They base this assessment on legal requirements, size, frequency and severity of impacts, and customer requirements. Regarding social sustainability, they are doing lots on site for "work life balance" e.g. massages, chill out zone, walks and bike rides... only in office areas rather than production as yet though.
E	Energy usage is the main one - electricity and gas – then disposal of waste to landfill. This is an assumption but based on costs and known CO_2 emissions.
F	The main risk is chemicals, but they have a low risk site, so most efforts have been towards energy reduction. The main impact they can have an effect on and save some money is energy - usage on site is quite high – so they focus on energy saving.
G	In the product use phase, fuel use and associated production of greenhouse gases are the main impacts - this is the largest impact in LCA of their products. In manufacturing the main impact is energy use, secondly (probably) resource depletion. They have done LCA on

	two of their products, although they found the results of limited use – respondent B was unsure what changes this information could drive.
H	Energy, waste material and water. These show up as major financial costs to the business so are likely to be major environmental impacts, and are also based on knowledge of their processes and site.
I	Electricity and gas (lighting and heating in particular). They have had assessments done by an environmental organisation, and also measure energy usage etc.
J	Energy is their main impact (not quite 40% of costs, but very high) – then water and packaging. They assess this by their own measurements and monitoring, and have also been assessed by an environmental organisation.

Summary – Most respondents felt that energy usage was their main impact. Other impacts discussed included water, waste materials and waste to landfill, packaging and resource depletion. Assessment was by (in order of frequency, most frequent first): Quantitive assessment but not full LCA; Cost of impacts; Compliance; Internal monitoring of impacts; Assumptions based on knowledge of their processes, site and situation; Customer requirements; and full LCA (Life Cycle Analysis). Some companies distinguished between impacts in manufacturing and in use phase of their products' lifecycles.

Question 17 - What (if anything) are you doing to reduce your impact?

A	A key area of focus was reduction of use of harmful chemicals.
B	They have a windfarm project (justify by cost of power), using ECA approved kit, energy efficiency, fluids management project, wood burner project, awareness program running. They are setting up systems to measure energy used within each department.
C	There is an energy efficiency drive in place and the company has just recruited an energy efficiency engineer. They are looking to recycle more, for example by waste segregation. This is a moral decision rather than a course of action based on economics. Cost is always the main driver.
D	They segregate and sell waste for recycling, and reuse waste (e.g. for purging moulding machines). Following a rationalisation project with customer liaison, they have been able to reduce the number of types of plastic they use and facilitate the sale of waste plastic. They design products to enable waste segregation, reuse and long life. They have reduced the amounts of hazardous products on site (JIT), reduced usage of plastic, powder (for powder coating), water and energy per unit part. They have reduced energy use for lighting. They have a smaller compressor that they use when demand is low to save energy, have fitted an air leak detector and also want to block off air runs when they are not in use.
E	They have made energy savings and fitted intelligent controllers for heat and light. They are purchasing “green” energy, mostly for altruistic reasons, and are sourcing recycled paper. They are making money from selling waste for recycling and reusing waste on site (e.g. shredding cardboard to use instead of bubble wrap) instead of paying for disposal. They want to look at reusable packaging. They are using water-based instead of solvent-based paints, and have surrendered license for VOC emissions. They treat effluent on-site.

F	They are designing out all hazardous or toxic materials and designing in recyclability in their products. They are investing in low-impact energy, have been segregating waste for recycling for 4 years and make significant efforts to find recyclers for their waste, and also source recycled paper etc. They have an environmental policy for purchasing. All their staff are trained in environmental issues. They invested in low energy lighting some years ago and are now investigating ground source heat. Their commitment goes well beyond compliance. All businesses in the group have to submit reports on environmental performance. They had a carbon trust report on energy usage very recently, just analysing it to decide what to act on.
G	There are opportunities for impact reduction in materials lifecycle, energy efficiency in logistics and production, and reducing wastes. Designing for customer requirements will reduce energy in use (customer wants to spend as little as possible on fuel and wants a lighter engine). Customer and business drivers are helping make them more sustainable. They are considering Product Service Systems which have the potential for environmental impact reduction, but feel they are limited on what impact reductions they can make to their product or processes.
H	The company specified a requirement environmental impact reduction in design of their new building. They recycle paper and metals in particular and specify supplier contracts etc. to reduce waste and make it easier to recycle it. The combination of these has halved waste to landfill. They are investigating a consortium with other local businesses to build a wind turbine.
I	They have implemented returnable packaging. They have an energy management working group. They are selling waste for recycling. They are rationalising lighting, solder supply and compressed air. They actively encourage environmental suggestions within their suggestions scheme, and have received valuable suggestions for environmental impact reduction. They have many community projects.

J	They have done a lot of work to reduce waste to landfill by reduction at source or diversion to recycling, composting or reuse. They're looking at Biomass for CHP from wood waste and peat. They have also done a lot of work to reduce energy usage by energy efficiency, checking for air leaks, and rationalisation (for example they are considering switching to electric drives rather than air, as air is not well suited to their production environment). They have done a lot of work on reducing their use of packaging.

Summary – The projects for environmental impact reduction are related to the main impacts identified, with companies for example looking for ways to reduce energy usage, source renewable energy, reduce waste to landfill and reuse waste, reduce packaging, use more benign materials, reduce water and compressed air usage. Several companies mentioned staff awareness and training, and some companies had environmental purchasing policies or initiatives of some kind.

Question 18 - What have you found most difficult during your efforts to become more sustainable?

A	Question not asked – new question, from company F interview on.
B	
C	
D	
E	
F	Cost (raising money to do things) and educating the whole workforce that they have a responsibility for environmental issues, in the same way that they now realise they have for health and safety.
G	Lack of freedom / design constraints.
H	Improvement of an inherently high-impact process.
I	Monitoring and targeting, because of the cost of doing it (equipment etc.) - this is something they're investigating at the moment and would allow them to target improvement activities more precisely.
J	Time! They have energy committees to give people time to look at these things, plus to share information between sites, and are considering employing someone on a placement to assess their carbon footprint - because it is a competitive advantage (advertising environmental credentials and reducing costs).

Summary – Among the five respondents to whom this question was posed, there was a wide range of opinions although there is an element of cost even in the answers which do not specify that as the main problem (the improvement of a high impact process could be done if money were no object; more time to take actions means less time doing other work and is also linked to costs, etc.)

Question 19 - Is environmental improvement a cost or an opportunity to your company?

A	Company A puts a positive spin on the requirement to consider the environment. There is often a cost to being more environmentally friendly but they can see there are often benefits too, although they are often on the "soft" side and thus difficult to measure. An example is that when they replaced the air conditioning fluids they used there was a high cost attached but there was a benefit as it made the system more efficient – but this was mostly noticeable in more comfortable employees which is difficult to analyse.
B	The company sees environmental improvement as a cost, but representative B is trying to change that.
C	If they are compliant there is an argument that enviironmental improvement is not really necessary. There is scope for some improvements but if they are not necessary for compliance they would be subject to cost/benefit analysis and payback time.
D	There is recognition of costs and benefits – it is easier to get approval for projects with demonstrable benefits.
E	They do some projects for altruistic reasons but also have found cost savings from impact reductions.
F	There are opportunities at the redesign level - not really a marketing opportunity, because everyone's doing it, and e.g. china and america aren't interested although ISO 14001 and environmental credentials are important to some customers. Future proofing is important. Some projects have associated cost benefits and good payback times.
G	Opportunity - e.g. recyclate is cheaper in many instances than virgin material (and shouldn't need recertification) - should be designed in for new models too - they already dissassemble end of life engines to remove parts that can be re-used.
H	There's almost always some cost, but if you're sensible about it, there's always an opportunity side to it too.

I	Opportunity – they have saved money with their environmental improvements. They have to justify projects, even if payback is five years, or softer returns (e.g. social projects in schools).
J	Opportunity - being lean helps them see that, and know how to measure and control it.

Summary – Most companies recognised that there were costs to some environmental improvement projects but there were often also benefits and opportunities for cost saving.

Question 20 - Have you followed any environmental or sustainability improvement implementation paths e.g. ISO 14001, EMS, natural step?

A	ISO 14001 is a requirement for them but not a business driver. ISO TS 16949 helped achieve this more than lean. Comply with RoHS and WEEE. Carbon Trust have visited.
B	They are working towards ISO 14001 re-certification, e-mission green project, Carbon Trust scoping study.
C	They are required to have an EMS, which is based on ISO 14001, but they do not feel they need to go as far as ISO 14001 and customers are not demanding it.
D	ISO14001 since 2001, they are a member of a waste and resource efficiency club, have been advised by the Carbon Trust, have had an audit by Envirowise audit and mentor and advise on best practice for Envirowise as well.
E	ISO 14001 because some customers demand it - sometimes their own tools would be better. They have had advice from the Carbon Trust. They will be getting 5 days free consultancy from the EST, including looking at alternative fuels etc. They are a member of a NISP industry forum and have been in contact with a wind power consultant regarding the possibility of erecting wind turbines on their sites.
F	They have had advice from the Carbon Trust, and a visit from a regional environmental group but this was not really any help, as they did not learn anything new. They had ISO 14001 accreditation for a few years.
G	Have ISO 14001. Dealt with the carbon neutral company, looked into going carbon neutral. RoHS and REACH have an effect on their supply chain, even though they do not directly affect company G.
H	They plan to achieve ISO14001 accreditation in two years.
I	ISO 14001. They have had advice from the energy Action group and energy saving trust.

J	They have had advice from Envirowise, Carbon trust, NISP and the British Retail Consortium.

Summary – ISO 14001 (either accredited, working towards accreditation, or basing an EMS on ISO 14001) is the most commonly mentioned, but advice from bodies such as the Carbon Trust or Envirowise is also common.

Question 21 - As a result of your lean implementation, did you observe any of the following…. Reduction in energy usage, reduction in waste, increase in sale / reuse of waste, ….

A	There was an initiative to extend the time between cleaning down some equipment, reducing the requirement for harsh cleaning chemistries. This is in line with lean thinking but was not a direct result of Webber's lean implementation although the lean initiative probably helped. They have seen a doubling of productivity from the same factory and although power usage has increased, it hasn't doubled. Scrap has reduced over the 4 years they've been implementing lean from 16% to 9%. These results are not all due to lean but it was certainly part of the cause. Lean helps them avoid the need to offshore which would mean e.g. more transport.
B	Lean has led to a general waste reduction but it is not integral.
C	Respondent A believes they may have reduced energy usage through Lean implementation but is not certain as it is not a measure they use. Respondent B is not aware of what the Lean implementation has involved.
D	They have seen a reduction in material usage, but not as much as they would like – there are ideas for more projects. Have done CI projects for energy usage, and waste material reprocessing in-house. Some lean projects have equal benefit financially and environmentally – the environment officer (respondent B) is involved in all projects in his health and safety capacity and so is in a good position to assess this.
E	They have taken out warehouses with associated reduction in energy usage etc. 70% of resources used are not adding value, so focussing on reduction of muda probably reduces wasted resources. They are reducing and reusing packaging.
F	They have reduced packaging materials. They changed a process to reduce lead time and as a result switched to a more benign and recyclable material, but respondent A thought this was the only instance of this type of mutual benefit – they are restricted by the limited number of suppliers for their components.

G	Factory redesign has massively reduced their costs and impacts to run. They find it difficult to quantify other changes, and it's also difficult to change processing methods for their product.
H	By value engineering, improving tooling, reducing waste, reducing packaging and general waste reduction, they simultaneously ensure they are compliant, save money and reduce impacts.
I	Difficult to state, because it's not directly measured. Packaging waste has reduced (e.g. direct delivery?), they can tell because scrap packaging is not piling up even though production has increased. Less electricity per unit. They cannot directly check the effects of particular lean exercises, but Sean is sure that they do make reductions. Lots of small changes from suggestions because people have started to think about ways to reduce waste. They have introduced returnable packaging for goods in and goods out, a project which started as a Lean project then was taken over by the environmental department. 5S asks people to turn off their computer at night.
J	Company J deliberately integrates environmental improvements with Lean. Examples are energy use reductions, reduced waste to landfill and packaging reduction, probably some water use reduction is due to Lean too.

Summary – Most companies felt that they had made environmental impact reductions through their Lean efforts, for example by energy usage reduction, reduction of material used, reduction of packaging. In general these reductions are not the intention of their Lean implementation, and respondents found it difficult to report impact reductions because they do not measure them. The exception to this is company J, who do deliberately integrate environmental impact reduction into their Lean implementation. Company I incorporate environmental improvement into their suggestions scheme and gain useful improvement ideas from this. Company D use Lean-like tools in their environmental impact reduction efforts but this was not a conscious effort to integrate.

Question 22 - As a result of your lean implementation, did you observe any of the following…. Increase in energy usage (on site), increase in transport miles, ….. Anything else that you feel made your company less sustainable / environmentally friendly?

A	None noticed.
B	Impact varies with volume of work and location. They need to reduce impacts associated with transport.
C	Respondent B feels that the adoption of lifecycle analysis would make a greater contribution to improving environmental performance than Lean.
D	Changing factory or cell layouts increases the need for localised lighting, because the main lighting is optimised for the old layouts.
E	They increased packaging of some parts/products to prevent damage - lean shows up whether this is additional cost though, and it prevents impact due to wasting damaged parts or products.
F	None noticed.
G	None noticed.
H	None noticed.
I	They've talked about making more frequent deliveries to keep their stock down, but not got there yet. Some suppliers run more frequent deliveries now - but might put other customers' stock on the van too so hard to say what the impact is.
J	None noticed.

Summary – It is possible that Lean could increase transport impacts or packaging, but again there are no measures so this cannot be confirmed. The increase in lighting due to changing layouts is confirmed.

Question 23 - The aim of this project is to use lean tools and adapt them to increase their sustainability benefits - what are your thoughts on this idea?

A	Sustainability could be seen as a side-effect of lean. They had not made the connection between Lean and sustainability before, but could see the link once it was suggested. They felt that highlighting it was helpful, and that perhaps the reason they hadn't noticed the link was that they have gained ISO 14001 already. Respondent A felt that legislation isn't powerful enough to force design for recycling and provide a disincentive to moving to lower cost economies for example. Fuel and raw material price increases will force environmental improvements and improve the business case for such improvements.
B	Respondent A - "Does Lean and sustainability go together? Absolutely. But I'm not going to get evangelical about saving the planet. It's about eliminating waste and doing the right thing in the right place at the right time".
C	Respondent B was sceptical about the benefit of Lean but felt that LCA in combination with Lean could also improve performance and sustainability.
D	It is important to work together and to know the tools. Measures as used in Lean would be an important aid to sustainability improvement.
E	There is a lot that can be done (to reduce environmental impacts) and there are ways that the two can work closely together. They have environmental targets in their CSPS, which they are revamping to become world class rather than compliant – the new system will drive improvement.
F	The question is very pertinent. There is a direct correlation between Lean manufacturing and environmental considerations. Providing a structure and logic to environmental improvement projects would be helpful.
G	Cost is the main link between the two. There is a large barrier before Lean and sustainability improvement, in that product design determines a lot of the production machinery design and thus energy usage.
H	Initial reaction is that this is a strange combination, but once you start thinking about it there are clear links. There is potential for use of VSM (energy stream mapping?) and Single Minute Exchange of Dies (examination in detail of all activities and the reasons for them).

I	They had decided to stick to seven wastes, but can see the benefit of using environmental ones too, so that people can look at those - might be a cue for more energy or packaging reduction suggestions - they could "and probably should" add environmental wastes to process assessment sheet.
J	Lean helps people understand - they can use tools to make environmental improvements, and site hygiene is better. SOPs can help best practice for environmental impact reduction (e.g. turning off line when you go for a break, waste segregation) become standard. They are using some Lean tools to map and track and identify areas of improvement in their waste streams. Envirowise use similar tools - mapping, KPIs, continuous improvement and maybe Just in Time?

Summary – After discussion of the idea of integration, most respondents could see benefits to the idea and began to suggest ways that Lean and environmental improvement could work together, although they had often thought it was a strange idea at first. Company C's respondent was sceptical but had not had the chance to discuss the idea (his responses had to be gathered by sending him the questions as a questionnaire) and it did not seem from his responses that he had been involved in his company's Lean implementation at all.

Appendix C - Company B training material

Learning to see Industrial Waste

Outline

- Objectives
- Waste is…
- Industrial waste is…
- (Company B)'s targeted industrial wastes
- Action!
- Activity
- Summary and Questions

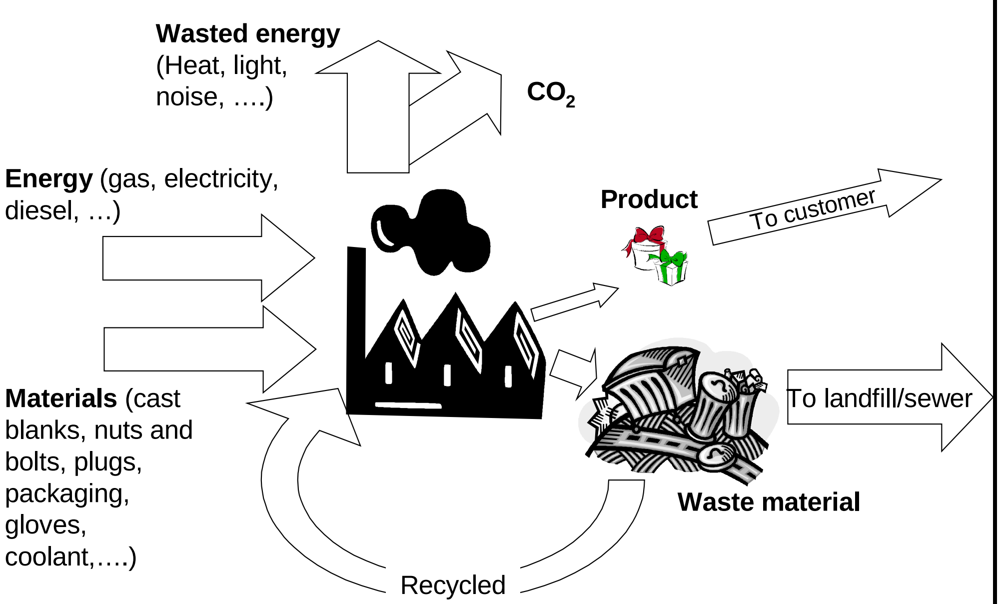
Objectives

- This course discusses wastes associated with environmental impacts, and ways that we can all help to reduce or remove them
- By the end of this course you will be able to –
  – Explain what industrial wastes are and why they are important
  – Explain how industrial waste fits into (the CSPS)
  – Discuss the potential causes and effects of industrial waste
  – Make useful industrial waste reduction CI suggestions

Waste is ….

Reproduction of company B's waste definition slide from standard waste training

Environmental waste is…



CO_2, waste, and recycling, and the eight wastes (1)

	Waste	Description	Impact on CO_2, waste and recycling
	Unused Creativity / Capability	Lost opportunities due to poor safety and a disengaged workforce	Improvement suggestions that could help reduce CO_2 or waste or increase recycling rates are not made
	Defects	Production or rework of out-of-specification parts	Scrapped parts and the CO_2 created in their manufacture and transport
	Inventory	Excess raw material, work-in-process or finished goods	Obsolete parts that are scrapped and the CO_2 created in their manufacture and transport
	Over production	Excess supply beyond the requirements of the next process	As for “Inventory”

CO2, waste, and recycling, and the eight wastes (2)

	Waste	Description	Impact on CO_2, waste and recycling
	Waiting	Lost time due to poor product flow; shortages, bottlenecks, down machines	Electricity is still used for lighting, heating etc. but no useful product is created
	Motion	Wasted movement made while working	Movements of machines use power and create CO_2
	Transport	Excess movement of work-in-process	Transport by vehicles produces CO_2
	Over-processing	Work that adds no value to the customer or business	Processes produce CO_2 but do not add customer value

CO_2

(company B commitment to CO_2 reduction

Did you know…

•CO_2 is a greenhouse gas – these gases contribute to the "greenhouse effect" and global warming

•We can use energy usage as a measure for CO_2

•Becoming more efficient and wasting less energy reduces CO_2 emissions

•(company B energy reduction target)

Using more energy than is necessary

CO_2 production

Potential Cause	Effect (Examples)	Notes
Leaving lights, computers, machines etc. on when they should be turned off	Electricity is still used up but doesn't do anything useful	YOU CAN – turn off when possible
Using more energy than is needed for a certain operation	Electricity is still used up but doesn't do anything useful	YOU CAN – make suggestions for ways to reduce process energy use
…………….	…………….	

Through employee involvement and Continuous Improvement, there is a great opportunity to reduce the amount of energy we use, which will reduce the production of carbon dioxide.

Waste

Did you know…
- (Company B recycling target)
- Materials
  – Copper figures – around 320 million tonnes have been mined until now. 1.4 million tonnes more are mined in the US per year, and recoverable reserves in the US are estimated at 90 million tonnes (16% of world total)

  (source: http://www.copper.org/education/history/g_fact_future.html)
- Landfill / disposal
  – The UK produces more than 434 million tonnes of waste every year. This rate of rubbish generation would fill the Albert Hall in London in less than 2 hours

  (source: http://www.wasteonline.org.uk/topic.aspx?id=19)

Waste material produced

Producing too much waste material

Potential Cause	Effect (Examples)	Notes
Excessive packaging waste	Materials (and energy etc.) are “used up” unnecessarily	YOU CAN – make suggestions to reduce packaging?
Printing errors	More paper and ink than is necessary is used	YOU CAN – print double sided? Make suggestions to reduce amount of printing needed?
Excess raw materials	Excessive material is disposed of as swarf	
High failure rate	More components are made than necessary (waste of raw materials, energy, ….)	
…….	………	

Through employee involvement and Continuous Improvement, there is a great opportunity to reduce the amount of material that is used up but does not add value

Recycling

Did you know…

- Materials
  - Manufacture of one ton of paper requires the use of 98 tons of various resources (including 64 t process water, 30.6 t process air and 3 t other materials and not considering resources used to generate energy and transport the paper)
    Source: Liedtke,C (1993)"Material intensity of paper and board production in western Europe", *Fresenius Environmental Bulletin*
- Energy
  - Just one recycled aluminium can saves enough energy to run a television set for three hours!
    source: http://www.recyclenow.com
- Disposal
  - (Company B waste targets)

Recycling less of the waste produced than we could

% Recycled

Potential Cause	Effect (Examples)	Notes
Recyclable material is not identified	Recyclable material is disposed of in landfill	
Recyclable material is mixed with other waste and becomes soiled	Recyclable material is disposed of in landfill	YOU CAN – separate waste as it is produced
……………..	……………..	

Through employee involvement and Continuous Improvement, we can find ways to separate out more of the waste we produce so that it can be recycled

Activity

- Go to your area and discuss possible green waste CI suggestions

Action!

(or, what we want you to do about green waste)

- Suggestions
- Measures
  - Number of green suggestions
  - How many are actioned

Industrial Wastes - Summary

- Industrial wastes are resources or energy that do not add value to the product
- The most important Industrial wastes for (company B) are CO_2 and waste materials
- As well as reducing these we would like to increase the percentage of waste materials recycled
- You can play a part in Industrial waste reduction through the CI suggestions scheme
- Industrial waste is also included in the 5S checklist

Questions?