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**ADOPTING LEAN MANUFACTURING TECHNIQUES IN SMALL
AND MEDIUM MANUFACTURING ENTERPRISES**

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**Adopting Lean manufacturing techniques in small and medium
manufacturing enterprises**

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ABSTRACT

Small and medium sized enterprises (SMEs) form a significant part of national and regional economic prosperity. They strengthen the capacity to generate employment and wealth for national and regional benefit. The importance of SMEs to the prosperity of a society and their contribution to new job creation, coupled with the recognition that they seem to underperform highlights the need to assist this group of companies improve their performance.

During the course of this research the author investigated whether SME manufacturing organisations had opportunities to improve productivity and performance, conducted a literature review of the application of cellular one piece flow and then tested a model to implement cellular one piece flow with three SME manufacturing organisations.

This thesis establishes that SME manufacturing organisations do have opportunities to improve productivity and performance through cellular one piece flow.

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PUBLICATIONS

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CHAPTER 1 INTRODUCTION

1.1 Introduction

This chapter sets the context of this research, both in terms of why it was undertaken and what it hoped to achieve. The aims and objectives are explicitly stated in Section 1.5 and Section 1.6 respectively. The chapter also gives a definition, for the purposes of this research, of Small and Medium sized Enterprises (SMEs) and sets the parameters within which the research was carried out.

The academic and industrial contributions of the research are identified in Section 1.9 and 1.10 respectively. The author considers the industrial significance of the research to be the most important; it is intended that the research will identify the benefits of applying a Lean manufacturing technique within SMEs and therefore act as a stimulus for other SMEs to adopt Lean manufacturing.

1.2 Stimulus for this Research

1.2.1 Personal Stimulus for this Research

The author has been employed in manufacturing for 16 years; the majority of his working life. This career has spanned from formative experiences during an engineering apprenticeship, progressing through into project, procurement and production management and most lately in service improvement. During this time, UK manufacturing has been under what seems to be perpetual pressure to increase productivity and reduce costs. When this research was first started in 2004, global competition, primarily from the rapid growth and development of low cost economies such as China, India and Eastern Europe were exacerbating the need for increased productivity and reduced costs (DTI report 2004). The DTI report (2004) identified an urgent and systematic need for manufacturing organisation to implement “best practice” such as Lean Manufacturing and other world-class methodologies. More recently, over the last 12 to 18 months, the global banking crisis and subsequent economic downturn have again meant external pressures are forcing manufacturing companies to reduce costs and improve productivity.

1.2.2 Industrial Sponsor

This research was carried out in collaboration with an industrial sponsor: MAS-East.

The Manufacturing Advisory Service (MAS) is a national programme of support to improve productivity of manufacturing companies. It is split into 10 regions which are coterminous with the 10 Regional Development Agencies (RDAs). The programme is jointly funded by the Department of Business, Innovation and Skills (BIS), formally the Department of Trade and Industry (DTI) and the RDAs across the UK. MAS-East covers the East of England and the RDA for the East of England is the East of

England Development Agency (EEDA). Businesses that have been supported by and followed MAS advice have saved over £500 million (BERR 2008).

The Director of MAS East was aware that cellular one piece flow was often prescribed by Lean manufacturing practitioners, including experts on his own team, as a means to improve productivity in cellular manufacturing systems. He was also aware that whilst there was an extensive literature on cellular manufacturing, the practice of cellular one-piece flow had received little formal attention. He was concerned that MAS could tarnish its reputation by advocating practices for which there was little research-based evidence. He therefore set the question: 'How can cellular one piece flow be rapidly implemented in SMEs to bring about improved productivity and performance?' The scope was defined by the industrial sponsor as SME manufacturing organisations in the East of England.

1.3 Research Domain

This research has been carried out with SMEs, see Section 1.4.3 for definition of SME, manufacturing organisations in the East of England. The East of England covers the six counties of Norfolk, Suffolk, Cambridgeshire, Hertfordshire, Bedfordshire and Essex.

1.4 Why this Research is Important

1.4.1 The Outlook for Manufacturing

'Manufacturing is vital to the United Kingdom's economy. It employs 3.5 million people directly and millions more indirectly through its supply chain.' (DTI Report² 2004). Patricia Hewitt, the Secretary of State for Trade and Industry, also comments that 'manufacturing globally is undergoing very rapid change.' The views of commentators has converged over recent years to the joint conclusion that manufacturing is vital to the UK economy (Trends in UK Manufacturing 2008)

The exact number employed in UK manufacturing varies between 2.8 million and 4 million depending on the source. As an example of this variation, The Manufacturing Foundation¹ claims the number to be over 3.89 million people (The Manufacturing Foundation, 2003) whereas Benchmark Research reported manufacturing to employ just under 3 million (Trends in UK Manufacturing 2008).

Whilst the exact number varies what is clear is that manufacturing as a source of employment has been in decline for more than four decades. At its peak in 1966, manufacturing employees in Britain totalled just under 8.5 million, nearly 37% of the

¹ The Manufacturing Foundation is an independent, not for profit think tank that researches into manufacturing issues and provides policy advice to Regional and National Government

total employed. The decline has been more or less continuous over this period. To give an indication of the magnitude of change in 1992 the share of jobs in manufacturing was around 18%, a decline of 53% in just 15 years (Shamy and Temple 2008).

The contribution manufacturing makes to the United Kingdom's gross domestic product (GDP) also varies depending on source. For example, a report by the Department for Business Enterprise and Regulatory Reform (BERR) states manufacturing accounts for 13% of UK GDP (BERR 2008). Whereas a report for the East of England Development Agency (EEDA) the national figure is quoted as 20% (EEDA Report 2004).

To put this in context it is worth noting that even the lowest figure of 13% equates to £150 billion a year towards the United Kingdom's GDP, making the UK the sixth largest manufacturer by output (BERR 2008). In terms of number of people employed, 4 million people equates to around 1 in 7 of the total workforce (EEDA Report 2004).

Manufacturing also requires goods and services provision, and thus manufacturing generates output and employment in other sectors which are not included in the above figures. When manufacturing output declines it will impact on these services and support providers.

Manufacturing is important to 'UK Plc' and is supported by the Government's manufacturing strategy. Manufacturing in the UK has also changed over recent years, with increasing competition from low cost economies meaning productivity needs to improve (BERR 2008). Manufacturing in the East of England has not been immune to these changes. Section 1.4.5 goes on to further explore manufacturing in the East of England and presents evidence to support the view that it is essential to the regional economy.

1.4.2 Productivity

Productivity, per employee, in Japanese companies is higher than that of most European companies. Gunasekaran (2000) cites an example in which the estimated productivity in 1991, in terms of cars per employee, was around 15 for Rover and Peugeot, less than 10 for Ford UK, 55 for Toyota in Japan and an expected 75 cars per employee in 1992 for Nissan UK (Gunasekaran et al² 2000).

UK manufacturing productivity is also significantly lower than our traditional global competitors of France, Germany and the USA. The exact level of the divergence varies across different sources, but ranges up to 55% higher productivity for these countries (Mahony and Robinson 2007), (DTI Report 2004), (Crafts and O'Mahony 2001), (The Sunday Telegraph 2005), (Manufacturing Foundation Report 2002), (EEF Report 2001) (Higon 2003). This divergence, and underperformance, is also true when just SMEs are considered (Khan et al 2007).

However this masks a significant improvement in UK manufacturing productivity over recent years with a 50% improvement in manufacturing productivity since 1997 (BERR 2008). Indeed, productivity growth in the manufacturing sector has outpaced the rest of the economy since 2003. In line with this manufacturing output has also grown solidly in recent years (EEF Report 2009).

Differences and variables between countries make comparison of national productivity difficult. For example the US benefits from economies of scale with the size of its market. The variability of currency and exchange rates also makes comparison difficult. It is beyond the remit of this Thesis to decide which is most accurate, or debate reasons for it. Comparison across currencies is always open to debate, but this is not the issue. Even if UK manufacturing was top in all of the productivity surveys it would still be important that it should continually be looking to improve and increase competitiveness. To give an example of the potential that improvements could give, the productivity gap accounts for around £70 billion of lost value add (EEDA Report 2004)

In addition to this the banking crisis which hit in the second half of 2007 and the repercussions for the world economy will have a significant impact on UK manufacturers. The Engineering Employers Federation² (EEF) consider the outlook over the next 18 months to be the weakest for nearly two decades (EEF Report 2009)

1.4.3 Definition of a SME

Different organisations and government bodies have different quantitative qualifiers for SMEs. The following all have or have had their own, slightly different, definitions;

- The European Commission
- Organisation for Economic Co-operation and Development (OECD)
- Department of Trade and Industry (DTI)
- Confederation of British Industry (CBI)

Others, such as Wynczyk (1993) have used qualitative measures to define SMEs. Similarly Farsigani and Carruthers (1996) believe SMEs are usually characterised by simple organisational structures which facilitate rapid decision making and often display a high degree of innovation.

For the purposes of this research SMEs are defined quite simply as employing less than 250 people.

² EEF is a members organisation for manufacturers, offering business services, government representation and industry intelligence.

1.4.4 SME Manufacturing

SMEs represented over 99% of the United Kingdom's 3.8 million businesses at the start of 2002. SMEs make a major contribution to the economy and account for around three in five workers (Khan and Bali 2007), this equates to around 12.6 million employees, and contributed £1,100 billion to UK turnover (52% of total), (Small Business Service Report 2003).

SMEs' share of manufacturing employment and output has been rising since the 1970s (Story 1994). Section 1.4.1 detailed the overall decline in the numbers employed in manufacturing over the last forty years. However this overall decline masks a significant shift in the share of employment in manufacturing to smaller organisations. Compared to the relentless fall in employment among large organisations, employment in smaller manufacturing organisations has declined far less. See Figure 1.1 below.

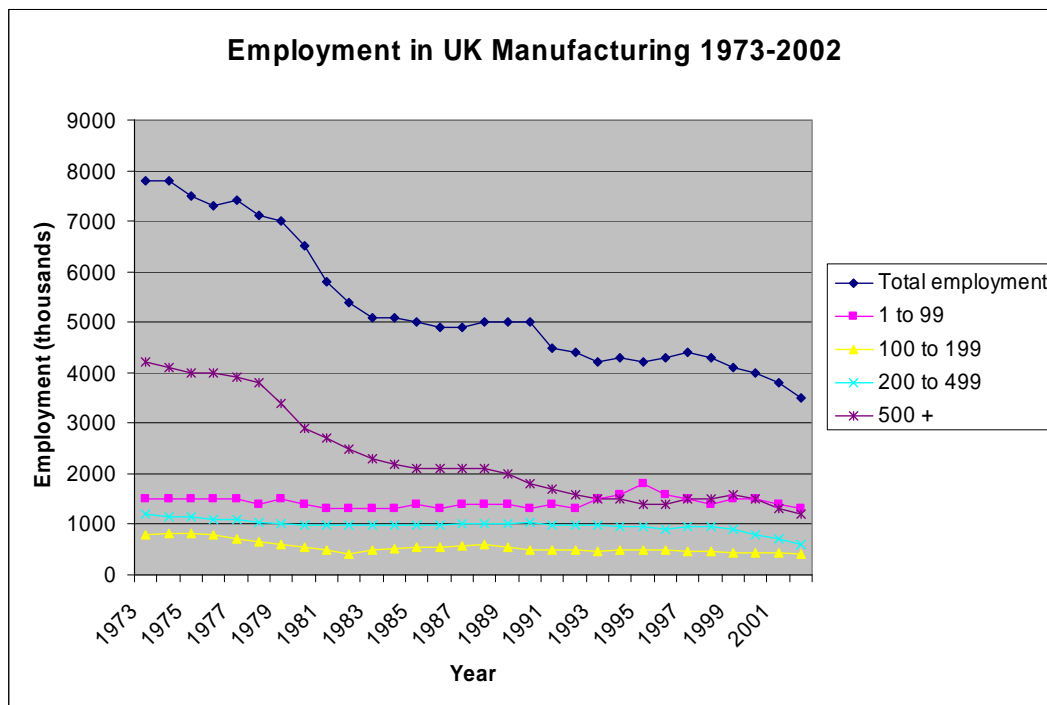


Figure 1.1 Employment in UK Manufacturing 1972 – 2002 (Shamy and Temple 2008)

This indicates SMEs are as, if not more, important in terms of employment and contribution to economy, than the larger organisations.

However, the size of an organisation, in terms of employee numbers, has been seen to impact on productivity (EEF Report 2001). The graph below, from the same EEF report, shows that organisations employing under 250 are typically around 50% less

productive than those employing between 4000 to 5000. Why productivity starts falling again when one considers 5000 plus employee organisations is not explained.

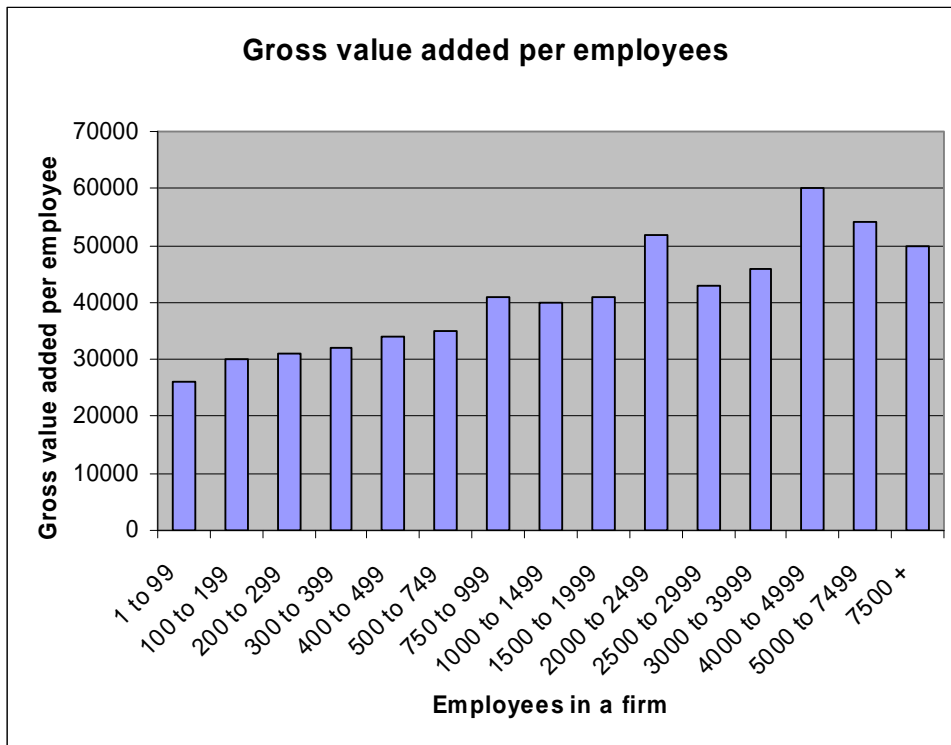


Figure 1.2 UK Manufacturing Productivity by Employment Size of Firm (gross value added per employee £) (EEF Report 2001)

The correlation between organisation size and productivity is supported by the Small Business Service. Their report shows productivity for manufacturing organisations employing under 250 people is £34,000 (gross value add/employee), and £45,000 (gross value add/employee) for organisations that employ over 250 people (Small Business Service Report, 2003).

1.4.5 Manufacturing in the East of England

The East of England had a manufacturing turnover of £38.4 billion in 2001, placing the region fifth, ahead of the East Midlands and London, in terms of manufacturing turnover when compared to the other regions of England (Office of National Statistics, 2003). See Figure 1.3 below.

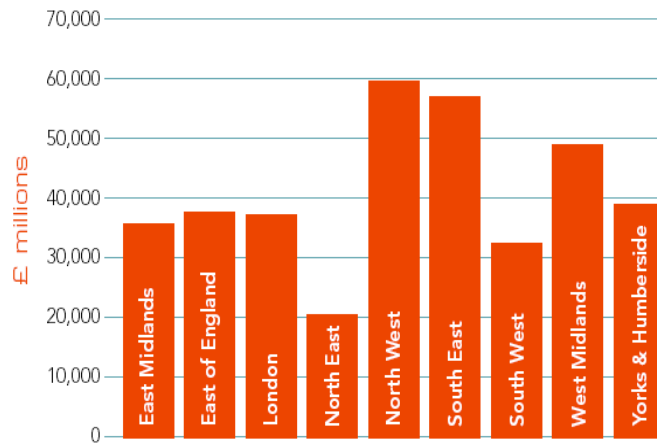


Figure 1.3 Comparison of UK Regional Manufacturing Turnover (ONS 2003)

Gross Value-Added (GVA)³ for the region was £85.8 billion, of which manufacturing represented 14.3% of this, down from 16.3% in 2000 and 20.0% in 1995. The East of England employed just over 327,000 people in manufacturing in 2001. This represents 14.4% of employment in the region, a fall from 354,000 (17%) in 1998 (Office of National Statistics 2003).

In 2003, the region was the third largest exporter of goods in regional terms, with £17.6 billion of goods exported. Between the period 1999 to 2003 the region ranked first in terms of average growth (8.4%), (HM Customs and Excise, 2004).

Manufacturing is the second highest wealth creating sector in the East of England in terms of gross value added (GVA). It accounts for 14% of total employment in the region, with a further three jobs dependent on each manufacturing job (EEDA Report 2004).

³Regional GVA is measured as the sum of incomes earned from the production of goods and services in the region. Under the European System of Accounts 1995 (ESA95), the term gross value added is used to denote estimates that were previously known as gross domestic product (GDP) at basic prices. Under ESA95, the term GDP denotes GVA plus taxes (less subsidies) on products, i.e. at market prices. UK regional accounts are currently only published basic prices so should be referred to as GVA rather than GDP. (From notes to section 12 in Regional Trends 2004 edition).

Manufacturing carries out the vast majority of research and development (R&D) in industry; £10 billion of £12.6 billion spent nationally in 2001. The East of England is second in terms of absolute R&D spend, with £1.2 billion. It is worth noting that there is a positive link with R&D spend and increased productivity (Kafouros 2005). Comparing East of England business with the UK average, the percentage of GVA spend on R&D for the East of England is 3.4%, over double that of the UK average of 1.5% nationally (OST paper on BERD, 2000).

The East of England has approximately 15,000 manufacturing companies. Official statistics for the number of companies (VAT registered manufacturing businesses) by turnover are shown in Table 1.1.

	Turnover Size (£ thousands)							Total
	0 - 49	50-99	100-249	250-499	500-999	1,000-4,999	5,000 +	
Companies	1,985,	2,580	3,175	1,880	1,445	1,955	740	13,760

Table 1.1: Manufacturing Companies in the East of England by Turnover Size

Source: ONS Number of VAT and/or PAYE based enterprises in 2009. Standard industrial classification (UKSIC 2007)

From the evidence presented in Section 1.4 it can be seen that manufacturing is vital to the East of England economy. Manufacturing nationally faces challenges, the East of England is not immune to these challenges. SMEs have been shown to have typically lower productivity than their larger counterparts. SMEs have also been shown to have a growing significance as part of the whole manufacturing sector. Therefore it can be concluded that research to support productivity and performance of SMEs within the East of England is a worthy endeavour.

1.5 Research Aim

The aim of this research is to identify: **How can cellular one piece flow be rapidly implemented in SMEs to bring about improved productivity and performance ?**

1.6 Research Objectives

To enable and support answering the research question the following research objectives have been identified:

1. Review whether SME manufactures in the East of England have opportunities to improve productivity and performance.
2. Carry out a literature review to identify whether cellular one piece flow delivers improved productivity and performance.

3. Develop and test a methodology for the rapid implementation of cellular one piece flow in SMEs.

1.7 Research Deliverables

The research reported in this thesis will result in the following deliverables:

- A literature review of the implementation of cellular one piece flow.
- A process, founded on previous research, for implementing cellular one piece flow.

1.8 Thesis Structure

This research thesis is composed of nine chapters as illustrated in Figure 1.4 below.

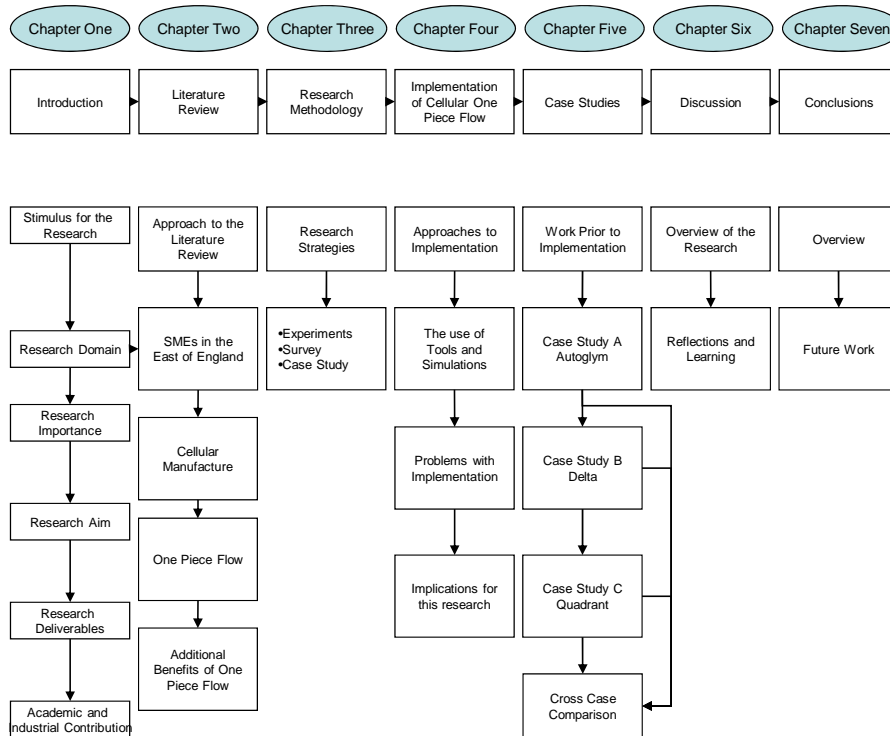


Figure 1.4 Thesis Structure

1.9 Academic Contribution and Originality of this Research

The author undertook a rigorous literature review as part of this research which set the direction of the research and was used as a foundation for the three case studies. There has been only a very limited amount of research on cellular one piece flow – the vast majority of work has been on only cellular manufacture. Although one piece flow has been widely applied in industry the number of research works has been small. The limited amount of previous research that has been carried out has typically focused on the scheduling and management of existing one piece flow systems (Li. and Rong 2009).

Of one piece flow Miltenburg (2001) states ‘Exactly how an implementation should be done is a subject that would benefit from careful research’ and ‘One piece flow production system is real and practical, not abstract and theoretical. So especially useful would be research that is anchored in real implementations’.

Therefore the novelty of this research is that it examines and tests a process for concurrently implementing cellular manufacture and one piece flow.

1.10 Industrial Significance of this Research

The vast majority of research and studies in the area of interest have been carried out in large organisations, with little research or publications focusing on SME organisations (Womack and Jones 1996) (Brown and Inman 1993), (Gunasekaran and Lyu, 1997), (Ramaswamy et al, 2002), (Karlsson and Ahlstrom 1997), (Gargeya and Thompson 1994).

A survey by the EEF (2009) found that just under three-fifths of manufacturing companies are currently utilising Lean manufacturing techniques. However there was a clear size difference apparent, with small companies less likely to have implemented it – 41% compared with over 70% for larger companies. This is supported by Khan et al (2007) who carried out a survey of 123 UK SMEs. They summarised that Japanese style philosophies, including Lean, were widespread in large manufacturing companies, but little attention, or knowledge, was from within SMEs.

From the research cited previously in this thesis, SMEs represent over 99% of businesses, contribute more to UK turnover and employment than large organisations and yet typically have lower productivity than larger organisations. Therefore the potential impact of this research in stimulating SME in adopting Lean manufacturing techniques could be dramatic, both to the individual organisations and collectively to regional and national economic prosperity.

The aim of this research is to demonstrate that manufacturers in the East of England have opportunities to improve productivity and performance and that the Lean manufacturing technique of cellular one piece flow can be used to improve productivity

and performance. It is the intention that this should add to the existing body of evidence and stimulate other SMEs in adopting Lean manufacturing techniques.

To fulfil the aim of stimulating other SMEs in adopting Lean manufacturing techniques it must address an immediate need and offer a rapid and sustainable improvement which has a high impacting result on the immediate need (Nelder, G. et al 2000).

1.11 Chapter Conclusion

The prosperity of manufacturing is important to the economy both nationally and regionally for the East of England. SMEs account for a significant portion of manufacturing, both in terms of number of employees and value of output.

UK manufacturing faces challenges in terms of productivity deficit from traditional competitors of Europe and the USA, the continued emergence of low cost economies and the global economic downturn. The East of England has a strong manufacturing base but it is not immune to these challenges.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

The aim of this research, as set by the industrial sponsor, is to answer the question of: **How can cellular one piece flow be rapidly implemented in SMEs to bring about improved productivity and performance ?** The scope for the research was SME manufacturing organisations in the East of England. There are two implicit assumptions in the research question and scope set by the industrial sponsor; that manufacturers in the East of England do have opportunities to improve productivity and performance; and that cellular one piece flow does bring about improved productivity and performance. The author felt it necessary to test and validate whether these assumption were true.

Through a literature review this Chapter examines these assumptions. Firstly, Section 2.2 details the author's approach and process for carrying out the literature review; and the results from this process. This identifies there are three key elements, or subjects, of interest in this research; SMEs in the East of England; cellular manufacture; one piece flow. Sections 2.3 to 2.5 then present the literature on each of these subject areas; Section 2.3 presents SMEs; Section 2.4 presents cellular manufacture; Section 2.5 presents one piece flow. Section 2.6 presents some additional benefits of choosing cellular one piece flow for this research, which were identified during the course of carrying out the literature review. Finally, Section 2.7 presents the Chapter conclusions.

2.2 Approach and Process for Carrying out the Literature Review

The approach to the literature review was split into 3 phases.

- (1) A 'background' review on SMEs, their importance and significance and relevant information on the East of England region. This element set the context of the research and was predominantly used in Chapter One.
- (2) An initial literature review of cellular one piece flow and the implementation of cellular one piece flow. This initial review was to obtain an indication of the type and quantity of research that had been carried out in this area. This initial review yielded approximately 27 papers.

Once this initial review had been completed and material reviewed the author decided upon and confirmed the research aim and objectives (as presented in Section 1.5 and 1.6 respectively) with the industrial sponsor.

- (3) The final element of the literature review was a detailed and focused search on implementation of cellular one piece flow, particularly in relation to SMEs.

This set the direction and formed the foundation for the research. It was therefore critical that a robust process for gathering information was used.

2.2.1 Problems Encountered with the Literature Review

There were difficulties in finding information that were specific and relevant to the area of the research topic. The three elements covered by the research topic are represented below in Figure 2.1. Numerous papers were identified that contained one or two of the elements but very few that contained all three elements. For example a paper might deal with one piece flow and cellular manufacturing but not SME, or cellular manufacturing and SME but not one piece flow. When the keyword search was expanded slightly an un-manageable amount of in appropriate papers were identified.

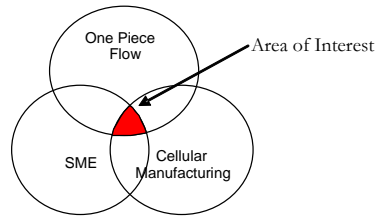


Figure 2.1 Area of Research Interest

Initial searches for relevant papers met with only very limited, ad hoc, success. After several weeks of frustration the author took time to reflect on the reasons why the search was not providing the relevant results. The reasons could be split into two main areas:

- The lack of a quantity of previous research that specifically matched the author's area of interest: implementation of cellular one piece flow in SMEs.
- The lack of a robust process for carrying out the literature review.

Lack of previous research was not something within the control of the author. However a robust process for carrying out the literature review was.

2.2.2 Process for Carrying out the Literature Review

Together with two members of the MAS-East team a brainstorming activity was carried out to identify all the 'keywords' that relate to the research area. These keywords included different variations of words, for example implementation and implementing, American spellings and words which were directly opposite in meaning, for example batch manufacture. These were then ranked into primary, secondary and tertiary keywords depending on how relevant they were to implementing cellular one piece flow in SMEs. The total number of keywords was 78. These are presented in Table 2.1.

<p>Primary Flexible Manpower Cell Flexible Manpower Line Flow Implement Implementation Implementing Implementing One Piece Flow Implementing Single Piece Flow One Piece Flow Single Piece Flow</p>	<p>Small and Medium Sized Enterprises Small & Medium Sized Enterprises Small to medium Sized Enterprises SME Sustain Sustainability Sustainable Sustaining Change Programme</p>
<p>Secondary Agile Agile Manufacture Agile Manufacturing Agile Production Assembly Assembly Cell Assembly Line Cell Cell Manufacture Cell Manufacturing Cell Production Cells Cellular Change Change Program Lead Time</p>	<p>Continuous Improvement JIT Just in Time Just-in-Time Lean Lean Manufacture Lean Manufacturing Lean Production Manufacture Manufacturing Methodology Model Process Improvement Production Improvement</p>
<p>Tertiary Application Batch Batch & Queue Batch and Queue Batch Assembly Challenge Change Agents Competition Competitive Flexible Improvement Japan Japanese Kaizen</p>	<p>Lean Methodology Lean Techniques Lean Tools Productivity Responsive Takt Takt time Toyota Value Stream Value Stream Map Water Spider World Class World Class Manufacturing</p>

Table 2.1 Keywords used for literature review

All the permutations, starting with primary keywords, of all the keywords were used in the literature search. Following consultation with Cranfield University research staff the following research databases were identified:

1. EBSCO (Bus Sour Prem)
2. ABI Trade & Industry
3. SCOPUS

The following databases were identified but not required. The reasons for this are explained in section 2.2.3.

4. FACTIVA
5. RAM
6. SCIENCE CIT IND (ISI)
7. WILLEY
8. SWETSWISE
9. EMERALD

Once the keywords had been identified the author then started to systematically carry out the literature search. The process followed was:

1. Enter a search query on the first keyword(s), for example Flexible Manpower Cell.
2. If this returned a manageable number of papers then these were reviewed. If an unmanageably high number of papers were returned (over 100) then a second search string, using the next keyword(s) from Table 2.1 was added to the first query, for example ‘small*’. – Truncation was used so that ‘small*’ would capture the various different forms of ‘small and medium sized enterprises’, ‘small & medium sized enterprises’ and ‘small to medium sized enterprises’.
3. If the use of two search queries returned a manageable number of returns then these were reviewed. If not then a third string was added.
4. Starting with the first keyword(s) and then systematically working through the various combinations. This is demonstrated in Figure 2.2. The first keyword of ‘flow’ returned 45065 papers. Therefore a second search of ‘implement*’) was added which reduced the number of papers to 1980. A third keyword of ‘sustain*’ was added which identified 26 papers (‘hits’). These were reviewed and one relevant paper ‘Lean production and sustainable competitive advantage’ was printed and read in full.

Search Phrase 1	Flow (45065)	Hits
Search Phrase 2	Implement* (1980)	
Search Phrase 3	Sustain*	
Restrictions		Relevant Hits
Search Parameter		
Comments	Lean production and sustainable competitive advantage , By: Michael A. Lewis, International Journal of Operations & Production Management, 2000, Vol. 20 Issue 8, p959.	

Figure 2.2 Systematic Keyword Search

- This process started with the first keyword and was repeated for all of the keywords identified in Table 2.1. After this was complete using the first search database (EBSCO) it was repeated for the second (ABI) and finally the third (SCOPUS).

2.2.2.1 Recording Searches from the Literature review

The combination of searching each keyword individually (78 searches) plus a combination of each word with each other keywords (77 x 77 searches = 5929) gave a theoretical total of 6007 combination of search queries. This would potentially be an unmanageably high number of individual searches queries to run. However this could be reduced by using one word, for example 'Lean' which would identify a series of key words/groups of words, for example, *Lean*, *Lean manufacture*, *Lean manufacturing* and *Lean production*. This greatly reduces the number of search queries that needed to be run.

However what this experience did highlight was the need to effectively and efficiently record the search queries to ensure all permutations could be recorded.

2.2.2.1.1 Recording Searches Version One

Initial thoughts on producing a sheet to capture the searches were to try and get it on one sheet, for simplicity.

The screenshot shows a spreadsheet with a magnifying glass over a specific section. The section is a table with the following data:

	PRIMARY	Flexible Manpower Cell	Flexible Manpower Line	Flow	Implement	Implementation
PRIMARY	0	0	0	0	0	0
Flexible Manpower Cell	0	0	0	0	0	0
Flexible Manpower Line	0	2	-	-	-	-
Flow	0	1.00	-	-	-	-
Implement	0	-	49065	-	-	-
Implementation	0	-	-	-	-	-

Figure 2.3 Version One of Spreadsheet to Capture Literature Searches

After a trial run it was found that because there was so much information on one sheet the text was too small to read when printed (unless it was printed on 24 separate sheets and they were sellotaped together). The trial also identified that it would be useful to capture information on the number of hits and the number of relevant hits, so that this information could be compared as the search progressed. For these two reasons version 1 of the spreadsheet to capture literature searches was not suitable.

2.2.2.1.2 Recording Searches Version Two

Version 2 of the recording sheet was much more user friendly in terms of size and ease of reading of the text. It also captured information on 'Hits' and 'Relevant Hits'. However it did run to 244 pages to capture all of the combinations. A screen print of version 2 is shown below in figure 2.4.

Primary Words

Search Phrase 1:	EBSCO	ABI	Emerald	Factiva	RAM	ISI	Wiley	Swetswi	Scopus
Flexible Manpower Cell	Hits	Hits	Hits	Hits	Hits	Hits	Hits	Hits	Hits
Search Phrase 2:									
Restrictions:	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits
Search									
Parameter:									
Comments:									
Search Phrase 1:									
Flexible Manpower									
Search Phrase 2:									
Productivity									
Search Phrase 2:									
One piece									
Restrictions:	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits
Search									
Parameter:									
Comments:									
Search Phrase 1:									
Flow									
Search Phrase 2:									
Talk time									
Search Phrase 2:									
One piece									
Restrictions:	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits
Search									
Parameter:									
Comments:									
Search Phrase 1:									
Implement									
Search Phrase 2:									
Restrictions:	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits	Relevant Hits
Search									
Parameter:									
Comments:									

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Figure 2.4 Version Two of Spreadsheet to Capture Literature Searches

However, after testing this version of the sheet the author found that the different search databases had different search criteria. Therefore to capture the information across all of the databases on one sheet did not prove to be a viable option.

2.2.2.1.3 Recording Searches Version Three

A third version of the recording sheet was developed. A screen print of the sheet can be seen below in Figure 2.5.

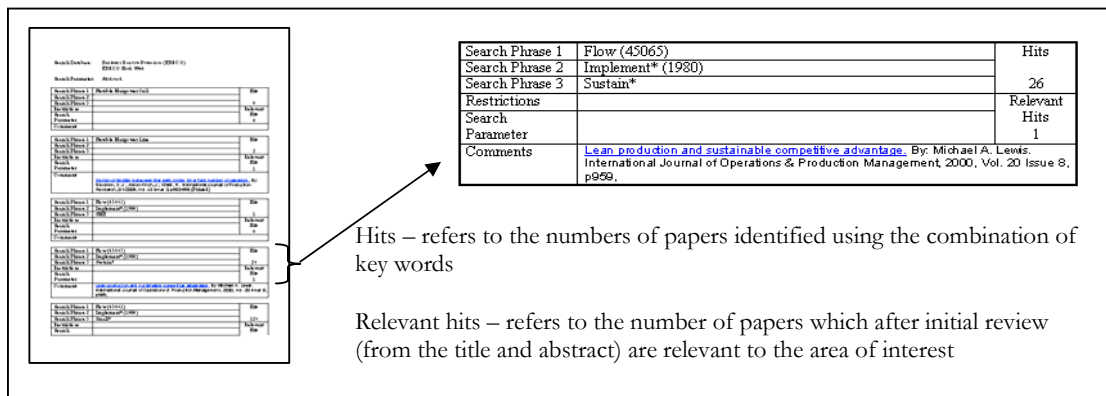


Figure 2.5 Version Three of Spreadsheet to Capture Literature Searches

Version 3 was a standard format that had flexibility to be used across all of the databases. Using truncation of words wherever possible also enabled the number of searches to be reduced. For example, ‘implement*’ was used instead of ‘implement’, ‘implementation’, ‘implementing one piece flow’ and ‘implementing single piece flow’.

2.2.2.2 Results from the Literature Review

The results from the searches run across the first three databases are presented below.

EBSCO (Database One)

Searches	114
Hits (Documents Reviewed)	3513*
Relevant Hits	52
Relevant Duplication Hits	27

ABI (Database Two)

Searches	59
Hits (Documents Reviewed)	1833*
Relevant (NEW) Hits	40
Relevant Duplication Hits	10

Scoopus (Database Three)

Searches	59	
Hits (Documents Reviewed)	2197*	
Relevant (NEW) Hits	5	13% of total
Duplication Hits	27	87% of total

* Hits (documents reviewed) was an initial review of the paper title to assess the relevance of the paper before deciding if a more in-depth review, through full reading of the paper, should be carried out.

2.2.3 Summary and Conclusions of the Process for Carrying Out the Literature Search

It is the belief of the author that through identifying the keywords related to the area of interest and then methodologically using the individual words and combinations of the words to search databases demonstrates a robust process for identifying published research.

Three separate research databases were searched using this process. The third database searched yielded an 87% duplication of papers which had already been identified by previous searches. Therefore the author had confidence that no further databases needed to be searched.

2.3 SMEs in the East of England

The aim of this research is to answer the question of: How can cellular one piece flow be rapidly implemented in SMEs to bring about improved productivity and performance? The scope for the research was SME manufacturing organisations in the East of England. Implicit in the aim and scope given by the industrial sponsor is that manufacturers in the East of England do have opportunities to improve productivity and performance. This short chapter examines, through analysis of some of the work carried out by MAS-East, whether this assumption is valid. In doing so it also addresses the first research objective: review whether SME manufactures in the East of England have opportunities to improve productivity and performance.

2.3.1 Scope and Nature of the Research Sample

Table 2.2 shows the number of instances in 2003 and 2004 in which MAS-East gave specific advice and recommendations, mostly through its ‘Manufacturing Review Day’ (see Section 2.3.2), against each of the seven measures of productivity mandated by the DTI. The table shows that in every case of a company seen by MAS-East there were opportunities to improve productivity and for the company to increase its value add. Personnel effectiveness was at the top of the list followed by lead-time and delivery issues, and in nearly half of the cases there were opportunities to improve space utilisation, reduce scrap and waste and get more from the equipment in place.

	People Productivity	Scrap / Defect Reduction	Space Utilisation	On Time Delivery / Lead Time	Increase Turnover	Equipment Productivity	Value Add Per Person
2003	221	85	98	161	66	80	121
2004	202	66	99	138	89	80	126

Table 2.2: Number of instances in which MAS-East gave recommendations against the DTI’s seven productivity measures

2.3.2 Manufacturing Review Day

The Manufacturing Review Day involved an experienced industrial practitioner - a ‘Manufacturing Specialist’ spending a full day with an organisation to carry out a hands-on assessment and diagnostic of the business. The aim of the day is to identify and highlight areas of opportunity or action that can be taken to improve operational performance. The day is provided free of charge to manufacturing organisations.

2.3.3 Analysis of MAS East Advice

The information presented in Table 2.2 resulted from advice given by MAS East Manufacturing Specialists during Manufacturing Review Day visits to just over 400 manufacturing companies in the East of England. In all of these visits MAS East Specialist were able to identify improvements that would improve productivity and performance.

This snapshot of East of England manufacturers indicates that manufacturers in the East of England do have opportunities to improve productivity and performance. The cohort of over 400 manufacturing companies varied in both size and the industry sector they served, giving confidence that they provide a reasonable representation of all manufacturers in the East of England.

A follow on session was held with the MAS-East Manufacturing Specialists team that had carried out these visits. During this session the observed barriers to adoption of Lean manufacturing techniques included; lack of awareness, inability to translate general knowledge into company-specific application and inability to make a business case for the quantitative benefits; all of which translate into a lack of confidence by manufacturing leaders in adopting Lean manufacturing techniques.

2.4 Cellular Manufacturing

The generally accepted definition of cellular manufacture is that it is based on Group Technology (GT), which aims to achieve increased productivity and efficiency by exploiting similarities in the manufacturing process of different products or parts of products. Parts that require similar processing requirements can then be grouped into a 'family'. A cell can then be formed which comprises the necessary equipment and human inputs to carry out the processing requirements and therefore produce the products/parts of that 'family' (Burbidge 1979), (Wemmerlov and Johnson 1997), (Boughton and Arokiam. 2000).

Cells can range from a single worker with no equipment (pure hand assembly) producing one part or product, to many workers with many machines producing a wide range of parts or products. The aim is to eliminate, or reduce, complex material flow patterns, work in progress (WIP), non value added (NVA) activities and increase productivity (Gunasekaran, A. et al 2001).

In his review of theory and practice of cellular manufacture, Miltenburg (2001b), identifies previous researchers that state 'of all the items in the JIT (Lean) tool kit, manufacturing cells are the single most powerful tool to reduce lead times and costs, and to improve quality'.

2.4.1 The Uptake of Cellular Manufacturing

In the Spraggett et al (1995) survey, of 23 UK medium to large organisations employing over 250 employees, all had to some degree implemented manufacturing cells.

Johnson and Wemmerlov (2004) research showed that cells are adopted by between 43% and 53% of organisations in the USA and UK with the uptake seemingly linked to the size of organisation; cells being more prevalent in large organisations. However whilst the findings of earlier research by Waterson et al (1999) are quite similar to Johnson and Wemmerlov in the percentage of organisations in the UK using cells - they found 40% uptake, they concluded that the extent of cell usage could not be attributed to company size.

In their regional study limited to the Greater Manchester and Merseyside region Boughton and Arokiam (2000) found 8 (25%) manufacturers from the responding survey of 32 used cellular manufacture.

2.4.2 Why Organisations Adopt Cellular Manufacturing

Reducing throughput time and reducing work in progress inventory were the highest scoring reasons cited in Wemmerlov and Johnson’s research, which covered 46 plants and a total of 126 cells, as the reasons organisations adopted cellular manufacturing. The top five reasons for adopting cellular manufacturing all related to throughput or response time (Wemmerlov and Johnson 1997). Reducing throughput time and WIP inventory were also the two most important reasons for introducing cellular manufacturing over 25 years ago (Burbidge 1979).

Typical benefits attributed to the implementation of cells included simplified material flows together with reductions in product handling, work in progress and throughput times. In addition, improvements are achieved in quality, schedule adherence and job satisfaction (Boughton and Arokiam 2000).

2.4.3 Barriers to the uptake of Cellular Manufacturing

Table 2.3 sets out the perceived barriers to the introduction of cellular manufacturing from the Boughton and Arokiam (2000) survey. In the survey, almost 70% of the SMEs were aware of cellular manufacturing. However only 25% used cells. The authors’ initial analysis of the product characteristics produced by the SMEs who had not implemented cellular manufacturing indicated two-thirds had products that fall into the medium to high volume category and should therefore, in their opinion, have suited cellular manufacturing.

Anticipated Difficulty	Respondents (%)
Lack of sufficient space	100%
Disruption to production	96%
Duplication of resources	91%
Introduction of new products	91%
Sharing of key resources	77%
Difficulty of moving machines	68%
Under utilization of resources	68%
Demand variability	46%

Table 2.3 Barriers to the Introduction of Cellular Manufacturing (Boughton and Arokiam, 2000)

Interestingly, cost was not cited as a significant barrier to the introduction of cellular manufacturing, which conflicts with previous research (Gunasekaran and Lyu 1997)

(Gargeya and Thompson 1994). However the questionnaire used to collect data was not available so the author was unable to determine whether limited options were presented to participants. Ambiguities and misunderstandings by respondents are a weakness of surveys and questionnaires (Robson 1993).

In the Johnson and Wemmerlov (2004) study of cell penetration in 150 organisations in the USA they found no dominant single factor, or even group of factors, to be universally important in preventing organisations from implementing cells. Instead they identified seven basic categories of factors that affect an organisation's decision to implement cells. They are:

1. Manufacturing Performance - It is well established that organisations implement cells to improve performance. If current performance is perceived to be acceptable it is unlikely cells will be adopted.
2. Demand Volume - Demand volumes need to be high enough to support dedication of employees, machines and equipment.
3. Demand Variability and Process Flexibility - Highly variable demand that is out of the control of the organisation and could cause either high over-loading or high under-utilisation would deter organisations from adopting cells.
4. Equipment Characteristics - If part of the process required equipment that was difficult to move, duplicate, miniaturise with a replacement or highly un-reliable this would restrict cell implementation.
5. Change Management Issues - These encompass all the human elements required, ranging from resistance to change, negative previous experiences, cost and time of any required training etc.
6. Time to Implement - Implementation, from the first data analysis work to moving employees and machine to training, takes time.
7. Justification - Cost justification can be difficult or onerous to complete.

(Johnson and Wemmerlov 2004)

2.4.4 Results from the Implementation of Cellular Manufacture

The author found numerous studies on the implementation of cellular manufacture. The results of implementing cellular manufacture, from the research studies, are described below.

Hyer (1999) developed a model to implement cellular manufacture. Two years after the implementation the organisation had achieved:

- Scrap reduced from \$40,000 per month to \$14,000 per month.
- Lead-time reduced from 10 - 15 days to 5 – 7 days.
- Monthly production volume of \$11,000,000 increased to \$20,000,000.

Chakravorty and Hales (2004) successfully tested the Hyer model. Measures were taken at 1 year and 5 years intervals after implementation.

Measure	Before	One year after implementation	Five years after implementation
Lead-time	7.7 weeks	3.8 weeks	1.6 weeks
Scrap rate	18.4%	9.8%	6.7%
Yearly volume (\$)	4.2 million	4.5 million	6.0 million
Number of workers	20	20	17
Yearly \$ volume / worker	0.210	0.225	0.353
Order active on floor (wip)	35	5	8

Table 2.4 Results of Chakravorty and Hales (2004) study.

Da Silveira (1999) carried out a study on implementing cellular manufacture through a team based approach in Brazil, with the following results.

Performance Measure	Functional Layout (Before)	Cellular Layout (After)	% Improvement
Scrap	5%	3%	-40%
Rework	30%	5%	-83%
Variety of products made in a day	12 (max)	40 (max)	+ 233%
Work in progress	7500 parts (average)	600 parts (average)	-92%
Final Stock	3800 units (average)	2600 units (average)	-32%
Batch sizes	100 – 1000 parts	50 – 100 parts	Up to 95%
Delivery time	15 days (average)	3 days (average)	-80%
Shop floor area	320m ²	180m ²	-44%

Table 2.5 Results of Da Silveira (1999) study

Wemmerlov and Johnson (1997) found the following average improvements from the 46 surveyed organisations that had implemented cellular manufacturing:

Reduction in throughput time	61% average improvement
Reduction in response time to customer orders	50% average improvement
Reduction in WIP inventory	48% average improvement

However only 29% of respondents claimed that the cells were established without acquiring new equipment. It is highly likely that the equipment would have given additional productive capacity and therefore not all of the improvement recorded could solely be attributed to the implementations (Wemmerlov and Johnson 1997).

Van Rhijn et al (2005) cite a 44% increase in productivity and 46% reduction in order lead-time. The time workers spent on value added activities went from 74% to 92%, and required floor space was reduced by 44%. Gunasekaran et al (2001) noted an increase in inventory in some areas, but in general a reduction in WIP. They also made improvements in machine utilization, scrap levels and output performance.

In the Boughton and Arokiam (2000) study of 32 SMEs, 75% claimed they had achieved a reduction in lead-time. 63% noted a reduction in changeover time, 50% an improvement in job satisfaction and 38% a reduction in WIP and improved quality.

However, results which have solely been reported by an organisation, without independent verification, should be treated with some caution. - It could be argued that no Manager or person responsible for the implementation is likely to volunteer their implementation as a failure. Olorunniwo's research, which used 57 questionnaires from US companies, and which the author claims to be the largest sample size of respondents of any survey dedicated to, or focusing on, cellular manufacturing implementation in the US, proposes that implementations cannot be deemed successful with a single measure.

The results from the different studies of the implementation of cellular manufacture all vary to some degree. Factors such as investment in new machine tools and other changes over time could also have had an effect on performance which was not solely attributable to the implementation of cellular one piece flow. However results of all the implementations show a positive impact on a measure of productivity or performance. This is congruent with a review of previous research on cellular manufacture carried out by Miltenburg (2001b) which concluded all the studies found reported significant improvements in productivity, work in progress inventory, throughput time and quality.

2.5 One Piece Flow

An overriding principle of cellular manufacturing is to arrange production work stations and equipment in a sequence that creates a smooth flow of material (Witt 2006). The possibility of achieving one piece flow is another benefit of adopting cellular manufacturing (Jing-Wen and Barnes 2000).

Put simply one piece flow is the process of 'make one, check one, and move one on' (Black 2007). It has at its heart the principle of manufacturing only to the demand of the customer(s). This concept of customer demand being the signal or authorisation to manufacture is classed as a 'pull system', - because the customer is 'pulling' the product. It is a very similar concept to JIT (Just in Time). This is very different from the traditional approach of a 'push system', where the company pushes product through the organisation to a forecast. One of the benefits of one piece flow is that it reduces lead times and is flexible and accommodates peaks and troughs in demand (Witt 2006) (Black 2007).

To achieve one piece flow, and improve productivity and performance, an organisation will have needed to have completed the process of cellular manufacture. One piece flow is considered the ultimate, and most difficult, step in achieving a Lean process (Miltenburg 2001) (Lander 2007)

Therefore it logically follows to implement one piece flow after implementing cellular manufacturing. However SMEs have been shown, by previous research, to want rapid

improvements. Therefore this research will aim to demonstrate that cellular manufacturing and one piece flow can be implemented together; to achieve cellular one piece flow.

2.6 Additional Benefits of Choosing Cellular One Piece Flow for this Research

As previously stated the research question: 'How can cellular one piece flow be rapidly implemented in SMEs to bring about improved productivity and performance', was set by the industrial sponsor. However during the course of this research, and in particular the literature review, additional benefits of choosing cellular one piece flow for this research have been identified.

The use of cells is central to Lean manufacture (Boughton and Arokiam. 2000), (Park and Han 2002), (Da Silveira 1999). Further to this Gunasekaran and Lyu (1997) believe the optimum starting point for adopting Lean is layout revision. Layout revision is central to cellular one piece flow. In their comprehensive, but relatively old, review of the small business and JIT, Brown and Inman (1992) found consensus in the literature that small organisations should firstly initiate Lean in areas under their control, i.e. internally to the business. There was, initially, no clear conclusion from the literature they reviewed on the particular technique to start with; however when their research was expanded to include analysis using a weighting system, layout revision was the highest scoring implementation step.

It is intended that this first step of cellular one piece flow will lead to the SMEs having confidence to take another step, and then continued steps, on the 'Lean Journey' to realise improved productivity and performance. Organisations that embrace modern improvement philosophies often rely on the principles of cellular manufacturing (Wemmerlov and Johnson 1997). Indeed, cellular manufacturing is considered an important element for further Lean implementations (Olorunniwo 1997) and in the USA 73% of manufacturing firms employing more than 100 people operate them (Hyer and Wemmerlov 2003).

Each cell is essentially a factory within a factory (Gunasekaran et al 2001). This gives the benefit for SMEs of adopting a powerful Lean manufacturing technique and proving its benefits in a contained pilot area, making it a less risky and more appealing step (Baker and Maropoulos, 2000).

In their research into cellular manufacturing and marketing strategy, Chambers and Nicholson (2000) found cellular systems can offer opportunities for almost any strategy.

With the exception of Gargeya and Thompson (1994) many authors suggest that significant improvements at very low cost can be made through the use of cellular manufacturing (Shayan and Sobhanallahi 2002) (Gunasekaran et al² 2000) (Chambers and Nicholson 2000). This should appeal to SMEs with limited resources.

2.7 Chapter Conclusion

This Chapter has described the approach and process used to identify previous research for the literature review. The author believes this demonstrates robustness in the process of searching for literature. This identified there were three main areas of interest to this research; SMEs in the East of England; cellular manufacture; one piece flow.

The research and analysis of the work of MAS-East, presented in Section 2.3, indicates that SME manufacturers in the East of England have opportunities to improve productivity and performance to meet their business needs. This short section also addresses the first research objective: review whether SME manufacturers in the East of England have opportunities to improve productivity and performance. With this need identified, the author could proceed to the next research objective: Carry out a literature review to identify whether cellular one piece flow delivers improved productivity and performance.

Sections 2.4 and Section 2.5 explained cellular manufacture and one piece flow. They tested, through previous research, the assumption that cellular one piece flow improves productivity and performance. In doing so it answers the second research objective: Carry out a literature review to identify whether cellular one piece flow delivers improved productivity and performance. The literature demonstrates cellular one piece flow does improve productivity and performance. With this assumption tested and validated the research could continue. One piece flow was described as the final, or ultimate, step in achieving a Lean process. A step that required cellular manufacture to be in place. The author intends, in the case studies, to implement cellular manufacture and one piece flow concurrently, to achieve cellular one piece flow. – And therefore respond to SMEs desire for rapid improvements. (Nelder, G. et al 2000).

The Chapter then went on to offer additional benefits of using cellular one piece flow in this research. - If a primary motivation and intention for carrying out this research is to stimulate SMEs to adopt and obtain the benefits of Lean manufacturing techniques then it is the author's belief that cellular one piece flow is an ideal place to start. Previous research on cellular one piece flow demonstrates:

- Cellular one piece flow is central to Lean manufacturing.
- Layout revision, which is central to cellular manufacture, is the optimum starting point for adopting Lean
- Cellular manufacture is a low risk step, not limited by different marketing strategies and typically low cost.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Introduction

This chapter firstly examines different research strategies. Section 3.3 follows with a discussion on which research strategy is best suited for this research. Section 3.4 describes the research approach, methodology and data analysis process employed during the different stages of this research. This is followed by explanation and rationale of the research domain and the overarching research plan.

3.2 Research Strategies

Research strategies can be classified in many different ways, one simple and widely used approach distinguishes between three main strategies; experiments, surveys and case studies (Robson 1993)

1. **Experiments:** Measure the effects of changing one variable has on another variable. The strengths of experiments is the clarity they bring to cause and effect relationships. However they require stringent design and control to guarantee validity and they do not offer good generalisability.
2. **Survey:** Standardised collection of information from a number of sources. The strengths of survey is that they do offer answers to general application. However the trade off is weakness in reliability of responses.
3. **Case Study:** Development of a detailed knowledge about one (or more) 'case'. Case studies offer in depth analysis in a research area. The weakness is there will be a limited number of case studies that a piece of research can carry out and therefore questions of the true representativeness of the findings. (Robson 1993)

Yin (2003) provides a useful overview table of the different research strategies.

<u>Strategy</u>	<u>Form of Research Question</u>	<u>Requires Control of Behavioural Events</u>	<u>Focuses on Contemporary Events?</u>
Experiment	how, why?	Yes	Yes
Survey	who, what, where, how many, how much?	No	Yes
Case study	how, why?	No	Yes

Table 3.1: Relevant Situations for Different Research Strategies (Yin 2003)

These three approaches represent different ways of collecting and analysing information. All have strengths and weaknesses, which means it is sometimes appropriate that research uses a combination of strategies, depending on the purpose of the research. The key in deciding which strategy or approach is used for research is the research question which is being answered (Manstead and Semin 1988) (Yin 2003). Therefore it is possible to use a combination or hybrid of these three types.

When considering the purpose of the research there are again three useful and commonly used classifications; exploratory, descriptive and explanatory:

1. exploratory: typically used to find out what is happening, ask questions, and gain new insights;
2. descriptive: typically used to accurately describe the subject area (person, event, situation etc);
3. explanatory: typically used to seek explanation in the subject area.

It is suggested by Robson (1993) that there is a relationship between the strategy and purpose. However Yin (2003) does not support this view and believes there can be considerable overlap in the combination of strategy and purpose. Robson's relationships are;

- case studies are appropriate for exploratory work;
- surveys are appropriate for descriptive studies;
- experiments are appropriate for explanatory studies.

(Robson 1993)

The weaknesses of these traditional approaches have led to the development of a different approach: Action Research. Action research is particularly advocated in studies involving human behaviour; because of the complexities and opportunities that arise from the enquirer and subjects being from the same species. For example; human values can be very variable and affect outcomes and humans have the ability to change during the course of the study. Action research, as the name suggests, is concerned with solving a problem (action) and furthering understanding and knowledge (research) (Robson 1993).

3.3 Discussion on which Research Strategy to use

The majority of the research identified in the literature review was based on either a (single) case study or questionnaire, these, along with experiment, are now considered as strategies for this research.

3.3.1 Experiment

The word experiment is typically associated with trying or testing something new. It generally involves changing one variable and measuring the effect this has on another variable. A central feature of experiment is that you need to know what you are doing before you do it, requires a lot of preparation and can usually only involve a small number of variables (Robson 1993). In addition Yin (2003) identifies that control of behavioural events are required to use experiment as a strategy. This will not be possible for this research, as it relies on different human intervention to bring about the change.

This research involves testing whether cellular one piece flow can be implemented in SMEs. The process of testing and answering this research question is complex and will have multiple variables. The process may also require adapting from the learning which occurs during the research. For these reasons the author feels that experiment is not an appropriate approach.

3.3.2 Survey

One of the strengths of questionnaire based research is that it can be carried out in many different organisations and therefore it has the potential to show greater applicability. However a weakness of the approach is that it has the potential to lack capturing the detail or nuances of the research area. Also, typically a survey is passive; i.e. seeks to describe and/or analyse the world as it currently is, also, they are not particularly well suited to carrying out exploratory work. (Robson 1993).

The industrial sponsor of this research has identified that this research needs to deliver a tangible change to a/some organisations as part of the research. Therefore a questionnaire based approach would not be suitable.

3.3.3 Case Study

Case studies tend to be the preferred strategy when answering “how” or “why” questions (Yin 2003). The research question this research aims to answer is a “how” question. One of the great strengths of a case study is its flexibility (Robson 1993). This would allow the case/cases to evolve and for the research to observe and record events. Another advantage of this approach is that it would allow the research to adapt and respond to the findings during the course of the research. However two common concerns of the case study approach is the lack of a systematic process and the lack of rigor, and the lengthy time it can take to complete (Yin 2003).

The case studies identified in the literature review were mostly single case study research. Whilst these were comprehensive, a weakness of the single case study

approach is that it could be deemed as inconclusive for generalisation and applicability to other organisations. Yin (1989 & 2003) makes the analogy that carrying out multiple case studies is like doing multiple experiments. They may be attempts at replication or they may build on a previous experiment, perhaps carrying out the research in a different area, or in an area suggested by the original research. Therefore they permit theoretical generalisation, and generalisation about the process, but do not permit statistical generalisation. This does not detract from multiple case studies, especially if from different contexts, having expanded external generalisability compared to a single case study.

One of the key drivers for this research is to stimulate SME manufacturer organisations into adopting and getting benefit from Lean manufacturing techniques. Case studies have high validity with practitioners (Serrano et al 2008) – the target audience of this research. Because of this a multiple case study approach was thought to be the optimal approach.

3.4 The Research Approach and Methodology Used

Two main research methodologies have existed for many years; qualitative and quantitative. However over recent years a new methodology has emerged: mixed methods (Creswell & Plano Clark. 2007). This methodology seeks to combine and exploit the strengths of both the qualitative and quantitative in one study.

The key factor in deciding which research approach and methodology is to be used has been identified as the type of question which the research aims to answer (Manstead and Semin 1988) (Yin 2003). Therefore it is entirely appropriate to use a combination or hybrid of the three research strategies previously discussed.

The research methodology, used for this research, can be split into three stages, which align with the research objectives as outlined in Section 1.6. Table 3.2 identifies the research objective and the type of research methodology and the data collection process used to achieve each of the objectives.

Stage	Research Objective	Type of Research	Type of Data
One	Review whether manufactures in the East of England have opportunities to improve productivity and performance.	Descriptive	Quantitative
Two	Carry out a literature review to identify whether cellular one piece flow delivers improved productivity and performance.	Exploratory	Qualitative
Three	Develop and test a methodology for the rapid implementation of cellular one piece flow in SMEs.	Exploratory - Case Study Action Research	Mixed methods (Qualitative and Quantitative)

Table 3.2 Research Objective and Research Methodology

The type of problem or objective determines whether the research is exploratory, descriptive or casual (Zikmund 1997). Classifying the research objectives based on their purpose provides a link between the problem and the choice of research used (Yin 2003) (Creswell & Plano Clark. 2007).

3.4.1 Stage One

The purpose of descriptive research is to “describe the characteristics of a population or phenomenon” (Zikmund 1997). To answer the first research objective a quantitative description, from analysis of MAS-East information, was presented to demonstrate that manufacturers in the East of England do have opportunities to improve productivity and performance.

3.4.2 Stage Two

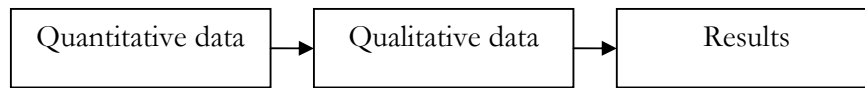
The research methodology for stage two was predominately a literature review. The literature enabled a review of current practice and thinking on cellular one piece flow application and led to a theoretical process for the implementation of the one piece flow cell. This stage, as advocated by Yin (2003) and Hart (1998), was used to develop and ‘sharpen’ the final research question.

3.4.3 Stage Three

After validating the research problem in stage two, case study research, employing a mixed methods (quantitative and qualitative) methodology, was selected for the third stage of this research. By using a mixed methods methodology the strengths of both approaches (quantitative and qualitative) off-set the weaknesses (Creswell & Plano Clark. 2007). For example; the experience, feelings and perception of participants are not explored in quantitative research but they are in qualitative. Equally, qualitative research could be seen to lack substantive figures on any improved performance, quantitative research would include these types of ‘hard’ measures. As a result a mixed methods approach gives a more comprehensive picture of the process and outcomes. The central premise of a mixed methods approach is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone (Creswell & Plano Clark. 2007).

Primary data was via observation and semi-structured interviews with the people involved in implementation of the case studies. This qualitative data was supported by quantitative data on performance before and after the implementation of cellular one piece flow.

Figure 3.1 Approach to Mixing Quantitative and Qualitative Data



(Creswell & Plano Clark. 2007)

When the research changes from solely being concerned with understanding, to also being interested in directly bringing about change during the process of the research numerous issues arise (Robson 1993). Conventional research seeks to limit the degree of involvement of the researcher on the area being researched – in the interests of objectivity. However an alternate research approach, Action Research, seeks to directly influence the outcome of process of research through collaborative problem solving between the researcher and the research area.

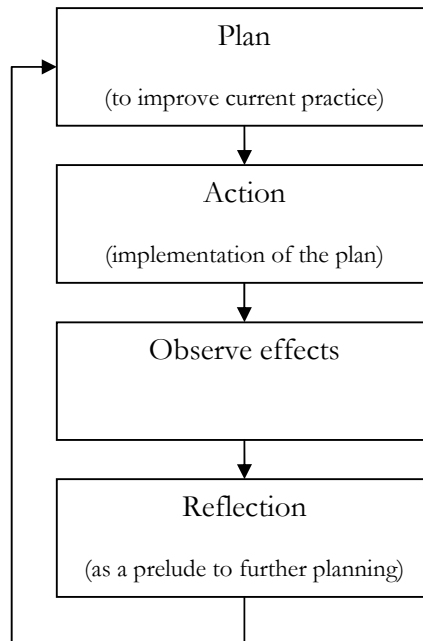
3.4.3.1 Action Research

Action research is a reflective process of progressive problem solving led by individuals working with others in teams to improve the way they address issues and solve problems. Kurt Lewin, then a professor at the Massachusetts Institute of Technology (MIT), first coined the term “action research” in about 1944. In his 1946 paper “Action Research and Minority Problems” he described action research as “a comparative research on the conditions and effects of various forms of social action and research leading to social action” (Wikipedia 2010).

Action research aims to contribute both to the practical concerns of people with an immediate problematic situation and to the goals of social science by joint collaboration (Rapoport 1970). The emphasis on a specific situation, and trying to produce change in that context, puts action research firmly within the case study strategy (Robson 1993).

Put simply, action research is “learning by doing”, for example a group or team of people identifies a problem, does something to resolve it and evaluates how successful their efforts were. If not satisfied they try again. This iterative approach has similarities with continuous improvement, a central principal of Lean (Lander and Liker 2007). The action research cycle is shown in Figure 3.2.

Figure 3.2 – The Action Research Cycle



(Robson 1993)

Action research was chosen for stage three as it satisfies both a pragmatic approach to the implementation of cellular one piece flow and it enables the author to review the process used for implementation to see how it can be improved.

The kind of thinking done by researchers is often theoretical rather than practical. A desired outcome of this research is that it will be of practical value and help stimulate manufacturers into action. Therefore Action Research better supports this outcome over a more traditional theoretical approach. This is complimented by the mixed methods approach to data collection. Creswell & Plano Clarke (2007) believe a mixed methods approach is best suited when the focus is on the consequences of the research and orientated on “what works” in practice.

An additional benefit of the Action Research approach is that members of the group (in this case the implementation team) are empowered to contribute both to the ideas that go into their work together, and also are part of the activity that is being researched (Hart 1998). This should increase the likelihood of changes and achievements of the case studies being sustained.

3.5 The Research Domain

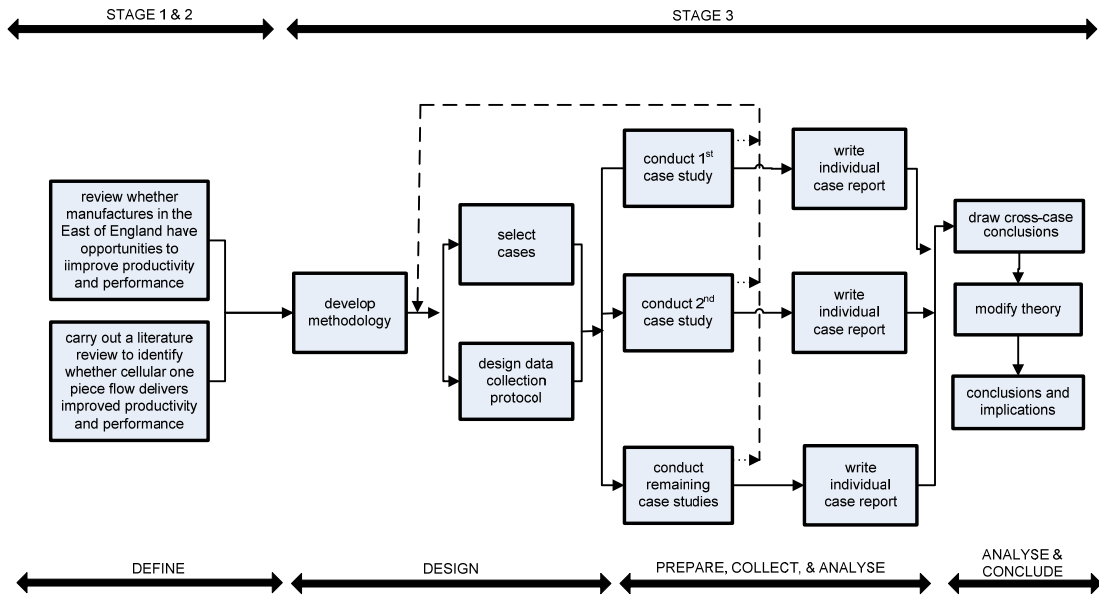
Three companies were selected to carry out the research. The three companies all meet the criteria of being a SME as laid out in section 1.4.3. The companies were purposely chosen from different manufacturing sectors to show greater external generalisability (Yin 2003). The companies will be from; automotive, electronics, and information and communication technologies, all of which are from the Regional Development Agency (RDA) priority list.

3.6 Chapter Conclusion and Overarching Research Plan

In conducting research numerous approaches can be used. The selection of a research approach is also based on the nature of the research problem, the researchers' personal experiences and the audiences for the study. The aim of the research approach is to best answer the research question.. Some researchers have depended on existing knowledge, typically gained from a literature review, to answer a research question. The weakness of solely using this approach is that it is constrained by the breadth and quality of the available previous research. This weakness is especially pertinent if there is only limited previous research, as is the case in implementing cellular one piece flow in SMEs. An alternative approach, which builds on the first approach, is to carry out a literature review and build on this to develop a new approach, which is then tested in the real world. The learning from the real world testing is then used to refine the output. This option is particularly suited to this research as it builds on existing knowledge whilst testing the practical benefit.

The research strategy and approach has been directly linked to the research objectives. The overarching research plan is presented in Figure 3.3.

Figure 3.3 Overarching Research Plan



(Adapted from Yin 2003)

4.1 Introduction

The aim of this research is to answer the question of: **How can cellular one piece flow be rapidly implemented in SMEs to bring about improved productivity and performance ?** Chapter 4 presented evidence that validated cellular one piece flow can bring about improved productivity and performance.

This chapter examines the approaches used to implement cellular one piece flow from previous research identified through a literature review. It is intended that these findings will be used as the basis of a methodology for the rapid implementation of cellular one piece flow, which will be subsequently tested in three case studies.

4.2 Approaches to Implementation of Cellular One Piece Flow

Approaches to cellular manufacturing can be classified into two distinct approaches; pragmatic and optimal (Gunasekaran et al 2001). There are many authors who have produced very technical work using algorithms and the optimal approach (Onwubolu and Mutingi 2001) (Cheng et al 2001) (Yauch and Steudel 2002).

Many authors advocate a participatory and integrative approach with a multi disciplinary team from within the company (De Looze et al 2003), (Van Rhijn et al 2005), (Gunasekaran et al 2001) (Rajam Ramaswamy et al 2002) (Gunasekaran et al 2000) which should include the Cell Operators (Hyer and Wemmerlov 2003) (Da Silveira 1999). Similarly many authors believe there needs to be strong management commitment and support (Chakravorty and Hales 2004), (Gunasekaran and Cecille 1998), (Gunasekaran et al 2000).

In the Chakravorty and Hales (2004) case study, the President, General Manager and Chief Financial Officer visited the implementation team several times a day. The involvement of the senior management in discussing improvements was cited as being vital. In the Gunasekaran and Cecille (1998) study a Project Sponsor (someone with sufficient interest and authority in the project to ensure it progresses with adequate resources and priority), and a steering committee were cited as important features of an implementation.

Boughton and Arokiam (2000) believe that the knowledge and expertise necessary to support the adoption of cellular manufacture are unlikely to be present within small organisations. However this is not entirely supported by the results of their survey of 32 SMEs. Of the 32, 8 used cellular manufacturing but only 2 of those had used external support. Therefore 6 (75%) had implemented cellular manufacturing without external support.

Gunasekaran and Lyu (1997) believe the emphasis of implementation should be placed on reduction of throughput times. However this conflicts with a latter paper by the author Gunasekaran in which stock removal and lot size reduction were identified as the reasons that should be assigned higher priority than throughput improvement (Ramaswamy et al 2002). This indicates that cellular one piece flow can have a positive impact on more than one performance variable.

In their research into cultural factors affecting the conversion to cellular manufacturing in small businesses, Yauch and Steudel (2002) carried out literature research, primarily from the general field of organisational change and development, and identified 11 factors leading to successful organisation change:

- 1) Clear vision, purpose, goals, plans, strategy and definition.
- 2) Management support and leadership.
- 3) Clear performance criteria.
- 4) Clear roles, structure and authority; institutionalised changes.
- 5) Sense of urgency or tension for change.
- 6) Effective communication and involvement.
- 7) Effective rewards and incentives.
- 8) Changes adapted to the organisational context.
- 9) Follow through, sustained activity and plans for continuous improvement.
- 10) Adequate resources and empowerment.
- 11) Small steps and short term successes.

(Yauch and Steudel 2002)

4.3 Methodologies Used for Implementation

Hyer et al (1999) developed a series of steps that considers both technical and social dimensions of cell design and implementation. The comprehensive framework covers strategic, structural and operational issues, which they tested in a large electronic assembly factory in the USA.

Strategic

- Step 1 Identify the need for change.
- Step 2 Justification for change.
- Step 3 Decide who and how.
- Step 4 Develop cell design objectives.

Structural

- Step 5 Assign products and machines.
- Step 6 Make cell operators assignment.
- Step 7 Determine system layout.
- Step 8 Material handling/tooling.

Operational

- Step 9 Set job design and rotation.
- Step 10 Roles of supervisors.

- Step 11 Inspection / quality procedures.
- Step 12 Maintenance procedures.
- Step 13 Production planning and control.
- Step 14 Cost control.
- Step 15 Rewards and compensation.
- Step 16 Documentation control.
- Step 17 Training.
- Step 18 Cell performance.
- Step 19 Communicate the change.
- Step 20 Plan the change.
- Step 21 Evaluate and improve.

(Hyer et al 1999)

In support of the Hyer et al methodology, Chakravorty and Hales (2004) successfully tested it in an organisation that manufactured building products.

The distinction between strategic and operational issues identified by Hyer et al is also supported by Wu and Huang (2004) in their methodology for combining business process re-engineering and one piece flow. Their 5 step process is shown below:

Strategic

- Step 1 Establish vision and objectives.
- Step 2 Select process to be redesigned.
- Step 3 Describe and analyse the process.

Operational

- Step 4 Redesign and evaluate the process.
- Step 5 Continuous Improvement.

(Wu and Huang 2004)

Da Silveira (1999) carried out research on a team-based approach to implementation of cellular manufacturing in South Brazil. The research developed a methodology of implementation, as shown below:

Phase 1 (Preparation)

- 1) Case analysis (technical and organisational aspects).
- 2) Team formation (people related).
- 3) Definition of project outcomes.
- 4) Choice of pilot area.
- 5) Implementation of supporting techniques (e.g. set up time reduction).

Phase 2 (Definition)

- 1) Choice of cell formation methods.
- 2) Data collection.
- 3) Cells formation.

- 4) Cells scaling (i.e. size and number).
- 5) Cell design (i.e. layout).

Phase 3 (Installation)

- 1) Preparation.
- 2) Re-assignment of machines and people.
- 3) Cell management and feedback.

Da Silveira 1999

Da Silveira states that using this approach enabled the company to extend cellular manufacturing into other parts of the organisation.

In their implementation study, which focused heavily on ergonomics, De Looze et al (2003) propose a simple 4-step approach:

- 1) Forming multi-disciplinary team from within the company.
- 2) Analysis of the process.
- 3) Identify bottlenecks.
- 4) Improvements proposed and tested.

This participatory and integrative approach was also applied in a Dutch SME where the organisation operated the old batch system and the new flow system simultaneously. This reduced variables, such as changes in workforce, demand, and product type etc that could have affected comparison measurements (Van Rhijn et al 2005).

Gunasekaran et al (2001) used a 'trial method' of cell design and implementation within a British automotive SME following a 9 step process. The trial method used pilot studies and trial and error techniques with logical cell arrangement and family groupings:

- 1) Selection of Multidisciplinary team.
 - 2) Formation of part / product grouping.
 - 3) Final layout design.
 - 4) Defining goals.
 - 5) Identifying critical success factors.
 - 6) Conducting background (preliminary) work.
 - 7) Selection of performance measures.
 - 8) Implementation.
 - 9) Standardise and document.
- (Gunasekaran, A. et al 2001)

The similarities of these approaches to implementation are examined and discussed in Section 4.7.

4.3.1 Implementation Timescales

The Hyer (1999) study was conducted over four years but the duration of the implementation is not described.

During the first year of the Chakravorty and Hales (2004) six-year study the case study organisation intentionally restricted other initiatives and changes that would impact on the measured results. This should have greatly limited external factors that could have affected the results measured. However after the first year the organisation was subjected to normal improvements and influences. This does highlight that longitudinal case studies can be susceptible to external influences that affect results. For example, introduction of new technology and new working practices.

The Da Silveira (1999) study and Van Rhijn et al (2005) study were implemented over 15 and 9 months respectively.

Whilst the Gunasekaran et al (2001) research does not state a timescale it does comment that 'cell design and implementation is a complex... and daunting process'.

4.4 The Use of Tools, Simulation or Software

To aid analysis and implementation some authors use software simulation tools (De Looze et al 2003) (Baker and Maropoulos 2000).

However whilst the use of software simulation can be seen to be beneficial it does have two problems

- It could have a detrimental effect on involvement and participation of a team based approach.
- Unless the company has this software already this could be prohibitively expensive and therefore act as another barrier for SMEs.

In their survey Boughton and Arokiam (2000) found current design tools and methods were considered too complicated, too time consuming or too costly.

Other practitioners recommend the use of game or simulation. (Shannon and Fry 1993) (Serena et al 2005) (Johnson 2003). The benefit of this approach of involving the employees who are going to be part of the implementation and change is not only that it demonstrates Lean manufacturing, but does so in a pragmatic way that can open people's eyes to the gains that can be made by applying it in their organisation. It also helps towards forming team coherence amongst the implementation team.

4.5 Problems Encountered with Design and Implementations

In their survey of 46 organisations Wemmerlov and Johnson (1997) found that 'soft' (people) issues outnumbered 'hard' (technical) issues as factors considered of great importance to cell planning and implementation by organisations that had implemented

cellular manufacturing. The implication of this is that successful implementations are more dependent on people issues than technical issues.

The top three 'hard' issues identified were:

- 1) Equipment placement/cell layout.
- 2) Choice of equipment and material handling system.
- 3) Capacity planning and product flow.

The top three 'soft' issues identified were:

- 1) Employee involvement (particularly operators).
- 2) Planning for the conversion.
- 3) Education and training.

(Wemmerlov and Johnson 1997)

In their study, Gunasekaran and Cecille (1998) also found consideration of technical, organisational and people issues were all key elements of a successful implementation.

4.6 Critical Assessment of the Literature

Numerous research studies have been directed towards cellular manufacturing. The vast majority of this research has been with large organisations. Of these research studies a significant proportion were focused on 'theoretical algorithm' approaches. The limited number of research studies focusing on practical implementation were again typically carried out in large organisations. No research studies have explicitly focused on cellular one piece flow.

This lack of research in implementing Lean manufacturing techniques, such as cellular one piece flow, and the lack of clarity regarding how they can be implemented in SMEs, has led to SMEs not fully exploiting the benefits (Achanga et al. 2004).

4.6.1 Research Gap Analysis

Review and analysis of the literature identified the following research gaps:

- There is a significant volume of research on implementation of cellular manufacturing in large organisations but a very limited number of implementing in SMEs.
- There were no research studies explicitly focused on implementing cellular one piece flow in SMEs.

4.6.2 Research Question

The critical assessment of the literature, and the research gap analysis leads to affirmation of the research question:

- How can cellular one piece flow be rapidly implemented in SMEs to bring about improved productivity and performance ?

4.7 Implications for this Research

This Chapter examined previous implementations of cellular one piece flow. It is the author's intention that the case study research which the author will carry out should be based on and build on previous research wherever possible. The reason for this is two fold; firstly to try to ensure the best possible chance of success in the implementing of cellular one piece flow and secondly; to add to the body of evidence around SMEs benefiting from implementing Lean tools and techniques.

The literature review examined previous research into the approaches to cellular manufacturing and how they can be classified into two distinct approaches; pragmatic and optimal. It is the author's intention that this research stimulates others into adopting cellular one piece flow. Therefore a pragmatic approach will be used in the case study research. In addition to this pragmatic approach, SMEs have been seen to respond to rapid improvements (Nelder et al 2000). Therefore, the aim of the implementations will be to implement cellular one piece flow manufacturing as quickly as practically possible.

Many authors advocate a participatory approach to implementation, which includes future cell operators and senior managers from the organisation. Therefore the implementation team for the case studies will include the future cell operators, managers, and a senior manager as 'project sponsor'.

Because the implementations will be carried out in SMEs the author will not take up the use of steering committees, believing that because of the size of SMEs the 'project sponsor' will also satisfy this role.

Several authors call for there to be a clear and identified need or purpose of the implementations (Yauch and Steudel 2002) (Hyer et al 1999) (Wu and Huang 2004). Therefore this need or purpose will be discussed and agreed with the project sponsor of the case study organisations before any implementation takes place.

The literature review identified different approaches and models used for the implementation of cellular one piece flow. The models used in previous research are all slightly different; however they do have some similar themes:

- 1) A vision, goal, objectives, outcome or need for the change. This includes management support. (Yauch and Steudel 2002) (Hyer 1999) (Wu and Huang 2004) (Da Silveira 1999) (Gunasekaran et al, 2001).
- 2) Team formation - cross functional from within the organisation (Hyer 1999) (Da Silveira 1999) (De Looze 2003) (Gunasekaran et al 2001).
- 3) Evaluation and improvement (Yauch and Steudel 2002) (Hyer 1999) (Wu and Huang 2004).
- 4) Analysis of the process (Wu and Huang 2004) (De Looze 2003).
- 5) Rewards and compensation (Yauch and Steudel 2002) (Hyer 1999).

With the exception of point 5 ‘rewards and compensation’, all of the themes that featured in two or more previous research outputs will be used in the author’s research process. The reason for the exception of this point is that the author does not have authority within the case study organisations to grant any rewards or compensation.

In addition to the above elements the following will form part of the implementation process:

- Measures of performance before and after the implementation of cellular one piece flow - so that any improvements made can be quantified and validated by the case study organisation.
- Training in JIT/Lean. The reason for this is that the author is following a participatory implementation approach. For sustainability the employees of the case study organisation must understand, buy into and come up with the improvements themselves. This will help overcome the ‘soft’ issues identified by Wemmerlov and Johnson (1997) as barriers to implementations. Training and teamwork are also identified as key concepts to support the change process by Khan and Bali (2007) in their study of 150 organisations undergoing business process re-engineering. It will also enable the knowledge transfer of the design and implementation of cellular one piece flow into the case study organisations; enabling them to go on and carry out further implementations independently of any external support. To support this many authors advocate the use of games or simulations. The author will use the Buckingham Just in Time (JIT) simulation as part of the training.
- Improve the process and eliminate non value adding activities. The reason for this is to use the opportunity of implementing cellular one piece flow to improve the process, rather than simply transferring the existing, possibly wasteful, process into cellular one piece flow format.

Therefore the process to be used for the case study research is:

Process for implementing Cellular One Piece Flow

- 1) Identify Aims / Goals.

- 2) Form Cross Functional Team.
- 3) Get measures of current performance.
- 4) Analysis of the process.
- 5) Training in Lean.
- 6) Improve the process, eliminate Non Value Adding activities and implement.
- 7) Get measures of performance.

The timescales from the previous research and implementations also varies, ranging from Chakravorty and Hales six year study to the Van Rhijn study which was conducted over 9 months. However caution should be applied to the Chakravorty and Hales research timescale as although the research was carried out over a six year period it does not state the duration of the implementation. As previously stated, it is the intention of the author that this research appeals to other SME organisations. SMEs are generally short-termist and look to address immediate needs quickly (Nelder, G. et al 2000). Therefore to stimulate other SMEs, the three research case studies need to work within this requirement. Therefore along with the pragmatic approach the author endeavoured to complete implementations within a three month period.

4.8 Chapter Conclusion

This chapter has presented the previous research on the implementations of cellular one piece flow, including the implementation models used and the timescale for implementations. This goes someway to answering the second research objective, as stated in Section 1.6, in that it demonstrates that the cellular one piece flow can bring about business benefit. The chapter concluded by synthesizing the information from the presented previous research into a process the author will use and test in the case study research.

CHAPTER 5 THE CASE STUDIES

5.1 Introduction

This chapter presents the three case studies of implementing cellular one piece flow. Section 5.2 describes the type of organisation selected for the case study research. Section 5.3 sets out the work undertaken before the case studies took place. This is followed by sections 5.4 – 5.6 which detail each of the 3 case studies. Section 5.7 offers a cross case study summary.

All of the case studies followed the same process as described in Section 4.7. This was:

Process for implementing Cellular One Piece Flow

- 1) Identify Aims / Goals.
- 2) Form Cross Functional Team.
- 3) Get measures of current performance.
- 4) Analysis of the process.
- 5) Training in Lean.
- 6) Improve the process, eliminate Non Value Adding activities and implement.
- 7) Get measures of performance.

This process is represented graphically in Figure 5.1 below

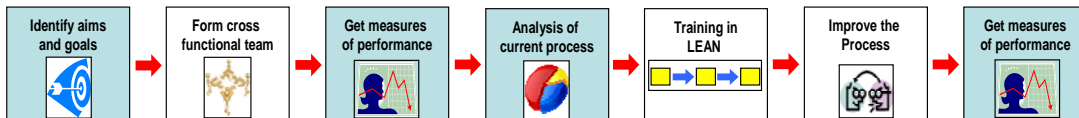


Figure 5.1 Process to Implement Cellular One Piece Flow

5.2 Type of Organisation Selected for the Case Studies

The Regional Development Agency for the East of England: East of England Development Agency (EEDA) has selected a number of manufacturing sectors that it believes are of the greatest importance to the future economic development of the region. These are: automotive and high technology manufacturing and advanced engineering including electronics, motor sports, environmental technologies, aerospace, defence, agricultural engineering, food processing, information and communication technologies, biotechnology and life sciences including pharmaceuticals. Companies in these priority sectors comprise approximately one-third of the Region's manufacturing base, which is very diverse (Source: FAME).

The case studies selected for this research were deliberately selected from the above priority sectors; to demonstrate the applicability of a Lean manufacturing technique to regional government. Each of the three case studies were deliberately chosen from different sectors; automotive (Autoglym), electronics (Delta), and telecommunications (Quadrant).

5.2.1 V-A-T Material Flow Analysis of Case Study Organisations

Organisations can also be differentiated by their production process and the way in which materials flow through this process. A taxonomy known as 'V-A-T analysis' provides a structure for analysing and categorising manufacturing operations. V-A-T analysis proposes there are three general categories of organisation (Hadas et al 2009) (Lockamy 2008) (Umble 1992) (Spencer 1995).

The product flow of a manufacturing process includes divergence points, convergent assembly points, and divergent assembly points. However, one of these three general categories of points will normally dominate the product/resource interactions in a manufacturing organisation. This leads to the three basic organisation classification categories (Umble 1992):

1. **'V Type'** Organisation
2. **'A Type'** Organisation
3. **'T'** Type Organisation

'V Type' Organisation

'V type' organisations are characterised by the existence of divergence points throughout the production process (Umble 1992) (Spencer 1995). 'V' organisations typically start with one or few raw materials or parts. The material/parts travel through a variety of different options of paths to result in a wide variety of finished products.

'A Type' Organisation

'A type' organisations are characterised by the existence of convergent assembly points throughout the production process (Umble 1992) (Spencer 1995). 'A' organisations are the opposite of 'V' type organisations, in that they start with numerous different materials/parts but finish in a limited number of final products.

'T Type' Organisations

The dominant characteristic of 'T' organisations is the existence of divergent assembly points at final assembly (Umble 1992) (Spencer 1995). 'T' organisations have a limited number of raw materials/parts, which follow a similar or the same process, but that have a final step(s) that provide multiple configurations of a final product. For example differences in colour or size of final product.

The different types of process flow of V-A-T organisation are shown in Figure 5.2 below.

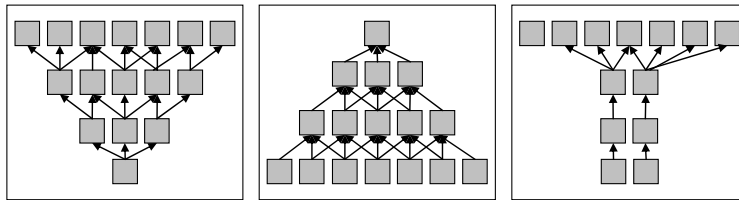


Figure 5.2 V-A-T – Three Different Types of Organisation

V-A-T Classification of Case Study Organisations

The three case study organisations are identified as the following type of organisation against the V-A-T model:

Autoglym – ‘T Type’ Organisation

Autoglym can be seen to be a ‘**T type**’ organisation. In the manufacture of the Lifeshine Valet Pack they start with a limited number of different parts. These are assembled into a wide range of final products, and all the different final products follow the same assembly process.

Delta Designs – ‘T Type’ Organisation.

The manufacture of Xenon Beacons at Delta Designs can also be seen to be a ‘**T type**’ organisation. In the manufacture of the Xenon beacon they start with a limited number (circa 30) of possible different parts. These are assembled into a wide range of final products (over 100). Importantly the products follow the same process for the different types of final product.

Quadrant – ‘T Type’ Organisation

Quadrant can be seen to be a ‘**T type**’ organisation. In the manufacture of the Jumper Cable they start with a very limited number of different parts. These are assembled into a wide range of final products (circa 50 – the most common difference is the cable length), and all the different final products follow the same assembly process.

5.2.2 Conclusions of Case Study Organisations Against V-A-T

Table 51 below shows the case study organisations against the V-A-T classification.

Organisation Type	V Type	A Type	T Type
Autoglym			X
Delta			X
Quadrant			X

Table 5.1 Case Study Organisations Classified by V-A-T Analysis

All three organisations are the same type of organisation. This gives strength; in that implementation in the same type of organisation will have been carried out and tested three times. However it will limit the applicability of the research to T type organisations.

5.3 Work Undertaken Before the Implementation

5.3.1 Step One – Identify Aims and Goals

Prior to the case study implementations a day was spent with each organisation to gain an understanding of the business, its needs and its constraints. Consideration was given to the length of time available to complete the research and the expectations of the organisation (Creswell & Plano Clark. 2007). The aims and goals of the implementation were discussed with key stakeholders to ensure they aligned with the business needs and that the organisation was ready to commit to the implementation of cellular one piece flow. The structure of the day is outlined in Appendix A.

5.3.1.1 Reasons for the Structure of the Day with the Organisations

In each of the case studies, critical success factors were agreed with each of the participant companies before the project was started. This was to ensure goal congruence among the team and also importantly to give a tangible measure of how much improvement, if any, was made as a result of implementing cellular one piece flow.

During the day, time was spent walking through the shop floor, talking to employees at different levels of the organisation, both individually and collectively, to follow the manufacturing process. Physically following and walking the process, as opposed to looking at standard operating procedures or other documentation, allows an understanding of the reality of process to be gained (Chen et al 2010). The reason for speaking to individuals independently - without management being present, was to avoid personnel giving answers to questions they felt the Managing Director or Senior

Manager would like them to say, and not the real answers or what actually happens. The reason for bringing everyone together at lunch was to flesh out any disparities in individual's views so that a collective team view could be agreed.

5.3.2 Step Two – Form Cross Functional Team

Team selection was a very important element to the success of the implementation (Hyer 1999) (Da Silveira 1999) (De Looze 2003) (Gunasekaran et al 2001). For each of the implementations, as a minimum, a cross section of key personnel directly involved in the process and the production / process manager were selected. The reason for this selection was to ensure that the personnel involved in the process, and therefore who knew it the best, took part in the implementation so any problems could be raised. The rationale is that those who are closest to the problem and the process are in the best position to come up with solutions and to implement them (Robson 1993). Another benefit of this selection is that it devolves authority to make improvements to the most appropriate level, improving ownership of the new process which increases the chances of sustainability.

In addition to this a Senior Manager 'Project Sponsor' was identified. The Project Sponsor would have the authority to make things happen and remove any organisational barriers that may arise.

5.4 Case Study A - Autoglym

5.4.1 Company Background

Autoglym was formed in the early 1960's and is based in Letchworth Garden City in Hertfordshire. They operate in the automotive sector, manufacturing vehicle care products to both trade and retail customers. Markets now include, PSV, Motorcycles, Caravans, Planes, Trains and Haulage, exporting to over 50 countries. The markets are highly competitive with constant price pressure on trade products and multiple strong competitors on retail products. They currently employ 105 people and have a turnover in region of £13 Million. One area of the business that has grown rapidly in recent years is the "Lifeshine valet and gift packs".

5.4.2 Step One – Identify Aims and Goals

The organisation identified the Lifeshine valet and gift pack as a growth area where they were currently struggling to keep up with demand and control costs.

The Autoglym Manufacturing Manager identified the following reasons for implementing cellular one piece flow:

“We had been looking at the Lifeshine valet and gift pack area and trying to think of ways to improve it for a while. We realised that this fairly new area of the business was growing rapidly and had recently been moved into a larger unit giving us more scope for change. As the assembly operation is a completely manual one we realised that labour costs would go up in relation the growth of this area. Anything that could be done to control these costs would be of benefit”.

The goal of the implementation was therefore to increase productivity and reduce labour costs.

5.4.2.1 Product Description

The Lifeshine kit is a valet and gift bag that contains products to maintain paintwork. The product retails at around £300 and from its launch in January 2003 Autoglym sold over 10,000 LifeShine kits in the first 6 months of operation. Trade customers include: Aston Martin, Volkswagen, Audi, and Seat. Figure 5.3 shows the Lifeshine kit product.



Figure 5.3 Autoglym Ltd – Lifeshine Product

5.4.3 Step Two – Form Cross Functional Team

The following team were identified as the implementation team:

- Manufacturing Director (Project Sponsor)
- Manufacturing Manager
- Team Leader
- Production Operator (x 3)

Only the Manufacturing Director and Manufacturing Manager had any knowledge or experience of Lean or cellular one piece flow.

5.4.4 Step Three – Measures of Current Performance

Before the implementation of the cellular one piece flow cell, the team ran two variants of the valet pack through the current process. The following results were measured:

Valet pack variant A: Number produced per hour = 9.3 packs.

Valet pack variant B: Number produced per hour = 8 packs.

The team operated with 6 assemblers.

5.4.5 Step Four – Analysis of the Current Process

Each operator collects a batch of each of the products required to fill the valet bag. A batch consists of either as many as they can carry in one go, or in the case of the actual bags; as many as they can fit in the space around them. The Operators then fill the bags with the individual products. Most Operators fill the bags in a slightly different order, then place them in a box before they are moved to the end of the assembly area and stacked waiting to be run on the 'Endoline' case sealing machine.

5.4.5.1 Manufacturing Area

The area in which the project took place was the 'Life Shine Assembly Area' which can be seen below prior to any changes.



Two Operators working on individual benches.

There are other Operator benches to the right of this photo and behind the partition wall

Figure 5.4 Autoglym Ltd Manufacturing Area

5.4.6 Step Five – Training in Lean

The author developed and delivered half day training in Lean as part of the first day of the implementation. This training covered the fundamentals of Lean and consisted of a presentation and a Lean simulation. The presentation used is shown in Appendix B.

The Lean simulation was used during the training. The aim of the simulation was to illustrate Lean concepts in a way that involves the team not only learning through participation but also in the decision making process. The team made the decisions on what improvements to make and were then able to see the consequences of these changes in a 'safe environment'. The simulation uses multiple products and has uncertain demand, both of which go to make it a realistic simulation. A detailed explanation of the simulation is given in Appendix C.. Appendix D shows photos of the Autoglym team playing the simulation and their 'performance'.

It became apparent during the Autoglym implementation, from feedback from the team, that it would have been better to have carried out the training in Lean (Step 5) before the team analysed the current process (Step 4). These two steps were switched for the next implementation.

Following the training in Lean the team started on the implementation of cellular one piece flow.

5.4.7 Step Six – Team to Improve the Process and Implement

The Project Sponsor set the expectations of the project and introduced the need for change. It was emphasised that senior management would support the team in achieving the improvements identified.

The team analysed the current process steps for assembling the Lifeshine kit and then went about improving the process to eliminate the inefficiencies. The team used an empty room of the main production area to test and mock up the new process. A digital photo of the mock up of the storage bins can be seen in Appendix E. Once the new process had been designed and tested there was a break of four weeks to allow Autoglym to build up a stock of production to enable them to lose a days production whilst the cellular one piece flow cell was implemented.

The implementation of cellular one piece flow was completed and 'de-snagged' within one day. Appendix F shows a digital photo of the team de-snagging the line. A further day was spent with Autoglym to 'cement' in the new process. To support this diagrammatic standard operating procedures were chosen so they could easily and quickly be understood by Operators that may be new to the process. Appendix G shows the new standard operator procedures produced for the cellular one piece flow cell.

5.4.8 Step Seven – Measures of Performance

On the first two valet packs run through the cell, the packs per person per hour increased from 9.3 to 18.6 and from 8 to 16.6.

Because of this, Autoglym achieved the following through implementing cellular one piece flow:

- Productivity increased by 101%
- An annual labour cost saving of £101,000
- Scrap / rework did not change – it was already at 0%
- Lead time was reduced by 40%

5.4.9 Qualitative Feedback from the Organisation

Following the implementation of cellular one piece flow, a sample of those involved in the implementation were interviewed. Those interviewed were; the Manufacturing Director, the Manufacturing Manager and a Production Operator. In addition to the quantitative measures recorded (Section 5.4.8), the following comments and observations were made by those interviewed:

- Subsequent to the implementation there was an increase in motivation and ideas for improvements coming from the team. It was felt this was attributable to the way that the implementation had been carried out, i.e. that the team had been involved, and felt empowered, to make suggestions of further improvements.
- The Production Operator commented that as he had been involved in coming up with and implementing cellular one piece flow, he felt personal ownership and responsibility for making it succeed.
- All those interviewed said they thought the Lean training and simulation were essential in getting understanding and buy in to cellular one piece flow.
- It was felt, by more than one interviewee, that the implementation could have been faster and there was a certain amount of frustration that they had to wait for the external support days to carry on with the work.
- Work in Progress (WIP), both within the process and waiting to supply the process, was significantly reduced.

The following is a direct quote from the Manufacturing Manager.

“When it was suggested that we would increase output using fewer people I was sceptical to say the least. The results speak for themselves I was very impressed with the knowledge of the facilitators and how they got the team to generate their own ideas” – Autoglym Manufacturing Manager.

5.4.10 Summary of the Autoglym Case Study

The implementation of cellular one piece flow at Autoglym was a success. The goals set out by the company of increasing productivity and reducing labour costs were

achieved (Section 5.4.8). The qualitative feedback from the company, and those involved in the case study, was very positive (Section 5.4.9).

The process was changed from individuals working in functional silos, producing and assembling part finished products in batches, to a team working in a cell. A diagram of the cell is shown in Appendix F. Within the cell products flowed through in a series of one, and each product fully completed when it reached the end of the process. Thereby achieving cellular one piece flow.

The level of engagement and buy in from senior managers and operations staff at Autoglym was high. All staff in the area, including those not directly involved in the implementation, were aware, and understood, what was going on and the reasons for the change. This undoubtedly helped the implementation of cellular one piece flow to be a success.

The implementation of cellular one piece flow at Autoglym was carried out in three days split over a three month period. The Manufacturing Manager and Operative both thought this could have been achieved more quickly.

5.5 Case study B – Delta Designs Ltd

5.5.1 Company Background

Delta Design work in the electronics sector. It was established in 1975 and manufactured its first light beacon product in 1978. In about 1990 Smiths Industries purchased the 'Timeguard' brand and product ranges from the Delta Design catalogue. Delta has become Europe's leading manufacturer of Xenon beacons, producing in excess of 300,000 beacons per annum in their own name as well as for Britax and Curtis, amongst others. They have 68 employees, 48 of whom are direct manufacturing staff.

They serve the automotive, industrial, agricultural vehicles, fire alarms and rescue/recovery vehicles markets with beacons and light bars. Their turnover was £3.6m in 2004, with 14% gross profit made.

The main pressure on their market is competition from rotating beacons and cheaper economies, especially China.

5.5.2 Step One – Identify Aims and Goals

The reasons Delta gave for undertaking the case study was the need to reduce costs. The organisation was finding the market increasingly cost competitive mainly due to the emergence of competing cheap imports from low cost economies. In support of reducing overall costs the company wanted to reduce and consolidate its manufacturing operations from the current six factory units that it rented.

The aim of the implementation was to reduce manufacturing costs and reduce the necessary floor space required to manufacture and hold stock for the Xenon product.

5.5.2.1 Product Description

The product manufactured was a flashing Xenon beacon of various sizes, colours, flash rates and voltages. Variants, of which there are over 100, range from a single small beacon to recovery bars with up to 32 flash tubes.

Lead times vary from one day for a standard (ex stock) beacon to three weeks for a new bar design. All products meet all the existing European quality and safety standards, unlike some cheaper imported products.

The unique selling point of the Xenon beacons over other rotating beacons is that on average their life span is over 20 times greater than that of beacons from other, usually cheaper, producers.

Figure 5.5 below shows a selection of the Xenon product range.



Figure 5.5 Delta Ltd - Xenon Beacon Product Range

5.5.3 Step Two – Form Cross Functional Team

The following team were identified as the implementation team:

- Managing Director (Project Sponsor)
- Production Engineering Manager (Champion)
- Quality Manager
- Manufacturing Manager
- Manufacturing Supervisor

- Supervisor
- Lead Hand
- Assembler (x3)
- Stores Supervisor
- Stores Person

The Managing Director and Production Engineer were the only members of the team to have some knowledge of Lean manufacturing techniques. Delta initially nominated the Manufacturing Manager as the Project Sponsor but it was felt that the Project Sponsor needed to be more senior, so it was agreed with them that the Managing Director would fulfil the Project Sponsor role.

5.5.4 Step Three – Measures of Current Performance

Before the implementation of the cellular one piece flow the team ran two variants of the Xenon beacon.

- Product A (Beta model): Number produced per hour = 6.2
- Product B (Gamma model): Number produced per hour = 5.7

The floor space used in the assembly of products covered 500m².

5.5.5 Step Four – Training in Lean

The Delta team was put through the same training in Lean as the previous Autoglym implementation which is detailed in section 5.4.6 and Appendix B.

5.5.6 Step Five – Analysis of the Current Process

The assembly process for the beacons is:

1. Kit batch of parts from stock.
2. Lace bases on bench.
3. Pack parts and return to stock holding area (in the assembly area)
4. Unpack part finished product.
5. Adhere internal label.
6. Fit 'O' ring.
7. Repack parts and return to stock holding area (in the assembly area).
8. Unpack part finished product.
9. Feed printed circuit board wires through base.
10. Align printed circuit board to base, secure with 2 self tapping screws

- a. PCBs are batch built to a common sub assembly level, of which there are approximately 150 variants. These are then carried in stock until required by the beacon assembly.

11. Flash test.
12. Fit lens.
13. Adhere product label(s).
14. Make up carton.
15. Insert product.
16. Insert leaflet, fixing kit & gasket.
17. Close carton.
18. Adhere carton label.
19. Place into outer carton.

5.5.6.1 Manufacturing Area

The area in which the implementation took place was the 'Xenon Beacon Area' on the 1st floor of Unit three. Work in progress stock and completed units were stored within unit one and unit two.

5.5.7 Step Six – Team to Improve the Process and Implement

The Project Sponsor introduced the need for change, setting the context and financial pressures that Delta were facing.

The team went about analysing the current process. Because the existing process was split over three units the team videoed the process so that it could be accessed and reviewed during the project. The team split into two teams, one team worked on the flow and handling of materials used and the other team focused on the flow of the product through the assembly. The two teams periodically checked back with each other to ensure their proposals did not conflict.

At the end of each day an action list was drawn up that identified the tasks to be completed during the break in support. This can be seen in Appendix I.

During the second day of support, the teams tested how the new flow of the products would work and also mocked up jigs and fixtures to use in the cellular one piece flow. Appendix J shows two of the jigs. The main area of waste was in unpacking part finished product, adhere internal labels and 'O' rings then repacking the parts. The parts would then wait around for up to one week before being unpacked again and consumed into product. At the end of the day the team had identified all changes necessary to implement cellular one piece flow. During the break between the second and third day the team communicated the proposed changes to the rest of the organisation.

5.5.8 Step Seven – Measures of Performance

The team ran two products through the new cellular one piece flow process, with the following results:

- Product A (Beta model): Number produced per hour = 7.2 (increased from 6.2)
- Product B (Gamma model): Number produced per hour = 6.6 (increased from 5.7).
- Scrap / re-work was reduced by 10%.
- Lead time was improved by 33%.

The cellular one piece flow cell operates within **70% of the original space required** and has shown an **increase in productivity of 16%**. Flexibility has also increased dramatically as Delta can now split the line into two and process two products at the same time. All of this has contributed to a **£233,000 growth in value added**.

5.5.9 Qualitative Feedback from the Company

Following the implementation of cellular one piece flow, a sample of those involved in the implementation were interviewed. Those interviewed were; the Production Engineering Manager, Quality Manager, Manufacturing Manager and two Assemblers. In addition to the quantitative measures recorded (Section 5.5.8), the following comments and observations were made by those interviewed:

- Some of the team, specifically the operators, felt uncomfortable with the approach and thought it was ‘managements job to decide and tell people how to do the work’
- The Manufacturing Manager acknowledged that the implementation of cellular one piece flow had been a success. However, he felt the resources, in terms of the number of people involved and size of the team involved made it questionable as to whether the benefits outweighed the costs and whether it had been worth the effort.
- In contrast to this the Production Engineering Manager felt the outcome was well worth the effort. He commented that the process for implementation, and the precedent this had set, had been more important for the culture and future working of the company than the outcome alone.
- Again, similar to the Autoglym case study, all those interviewed said they thought the Lean training and simulation were essential in getting understanding and some level of buy in to cellular one piece flow.

The following is a direct quote from the Production Engineering Manager

“Working as a team, of managers and production staff, we have improved performance and made the work more enjoyable.” – Delta – Production Engineering Manager.

However, contrast this with the following direct quote from an Operator

“I was uncomfortable with the process. The company said they were looking to save costs, we all know they need to save costs, and we were asked to change the work so less people were needed. Turkeys don’t vote for Christmas” – Delta – Operator.

5.5.10 Summary of the Delta Case Study

The implementation of cellular one piece flow at Delta was a success. The goals set out by the company of reducing costs and floor space were achieved. However the qualitative feedback from the company, and those involved in the case study, were mixed. This is discussed further in the cross case comparison (Section 5.7).

As previously discussed the main area of waste, through the batch manufacture, was in unpacking product, fitting labels and ‘O’ rings then repacking the parts. This is typical of a batch manufacture process, where products are part built in large batches and then stored. The waste associated with this process includes the waste of excessive transporting and moving parts around the shop floor, the associated increased risk this gives to damaging parts, the waste of holding excessive stock / work in progress and the waste of space required to hold this stock / work in progress. With cellular one piece flow this has now stopped so there has been a reduction in WIP and space. This means a corresponding reduction in the amount of lenses and bases held in stock from on average two weeks to one. The opportunities for damage have also been reduced.

The manufacturing process was changed from small groups working in functional silos, producing and assembling part finished products in batches, to a team working in a cell. Operators were now able to work on any part of the assembly process. This gave the company flexibility to move resources to cover sickness and holidays.

Within the cell products flowed through in a series of one and each product fully assembled, without batches of work in progress, when it reached the end of the process. Thereby achieving cellular one piece flow.

The implementation of cellular one piece flow at Delta was carried out over four days, split over a three month period.

5.6 Case study C – Quadrant Connections Ltd

5.6.1 Company Background

Quadrant Connections manufacture coaxial and multi-core cable assemblies for the telecommunications sector. The company was founded in 1986 and employs a staff of around 150 - depending on demand. They operate from a purpose built site in Radlett in Hertfordshire and had a turnover of 20 million Euros in 2004.

The UK and Europe-wide customers are in professional electronics, mobile radio and telecommunications, broadcast, data communications, instrumentation, marine electronics and many specialised manufacturers serving industries such as aerospace, automotive and healthcare. Export sales, primarily to continental Europe, account for over half of the company's turnover.

5.6.2 Step One – Identify Aims and Goals

The reasons Quadrant gave for undertaking cellular one piece flow were:

- Costs: large customers, such as Vodafone, require year on year cost savings from their suppliers (on average 10% reductions each year). Although Quadrant tried to pass the burden of some of these cost savings to suppliers they had only limited success. - Quadrant are relatively small purchasers, producing a niche product, therefore they have limited leverage over their supply chain. Subsequently the company was being forced to carry the burden of diminishing margins with the only option of reducing their manufacturing costs from within the company.
- Increasing competition from the low cost economies of China and Eastern Europe. Customers are taking designs and products to these economies and companies were producing similar, or even exactly the same, products at lower costs. As a way of mitigating this Quadrant were offering very short lead times, which could not be offered by overseas suppliers. Agility and responsiveness to quickly fill and deliver orders, especially for special products, was becoming a key competitive advantage for Quadrant. Therefore the ability to manufacture different products quickly was a key driver.

The critical success factors were to raise productivity and increase flexibility in responding to customer orders.

5.6.2.1 Product Description

The Jumper Cable is a very specialised product which is used primarily on mobile phone antenna masts and base-station systems, as an interconnection product to supply

the signal to the antennas. Therefore the customer base is almost exclusively broadcast and mobile communications servers and providers.

The jumper cable comes in variants in terms of both bespoke lengths and configurations of connectors, including Large (1/2") co-axial cables with 7/16 Male/Female/Elbow connectors. Figure 5.6 shows the Jumper cable product.



Figure 5.6 Quadrant Connections Ltd - Jumper Cable

Customer demand for lead times can vary depending on customer requirements, but range between five working days from receipt to despatch, although urgent orders must be able to be manufactured and packed within the same day (5-8 hours).

5.6.3 Step Two – Form Cross Functional Team

The following team were identified as the implementation team:

- Personnel Director (Project Sponsor)
- Manufacturing Director (Champion)
- Design Engineer (x 2)
- Section Leader
- Packing and Over moulding Operator
- Specials and 1/4" cables Operator
- Inspection Controller
- Supervisor
- Kitting Operator

The Manufacturing Director was the only member of the implementation team with any knowledge of Lean or cellular one piece flow.

5.6.4 Step Three – Measures of Current Performance

Before the implementation two different variants of the Jumper cable were run through the process. A 3 metre male to female straight connector cable and a 10 metre male to male elbow connector cable. Both variant took approximately the same time with an average cycle time to produce a complete jumper cable of 10 minutes with 15 operators contributing to the manufacturing process.

5.6.5 Step Four – Training in Lean

The Quadrant team was put through the same training in Lean as the previous Autoglym implementation which is detailed in section 5.4.6 and Appendix B.

5.6.6 Step Five – Analysis of the Current Process

The manufacturing process is described below:

1. Cable cutting – Cable is cut to size specified on drawing, which is created (individually) to customer specification.
2. Kitting – Connector parts and labels are linked to the cut cable.
3. Cables are stripped to drawing specification. – two operations, (outer corrugation and dielectric around inner conductor).
4. Cable is bead blasted to remove oxidation and grease residue in preparation for soldering.
5. Cable is fluxed and solder performs applied to outer and inner conductors, the back-nut of the connector and pin is then soldered to the cable using induction soldering stations, male and/or female.
6. The connector body is then screwed and torque tightened to the back-nut.
7. The cable is then tested for Return loss (100%) and Intermodulation performance (20%, 1 in 5 sample tested).
8. Once passed testing the cable is over-moulded, where a plastic boot seals the back-nut to the cable providing an IP 68 rating.

9. Caps are put onto the connectors to protect the pins and mating faces, then the cables are packed and put into stores.

5.6.6.1 Manufacturing Area

The area in which the implementation took place was the 'Jumper Cable Assembly Area'. Figure 5.7 shows the existing layout and flow of the product and the new layout and flow of the project after implementation of cellular one piece flow. The scale of footprint for before and after is the same to give an indication of the reduced space used.

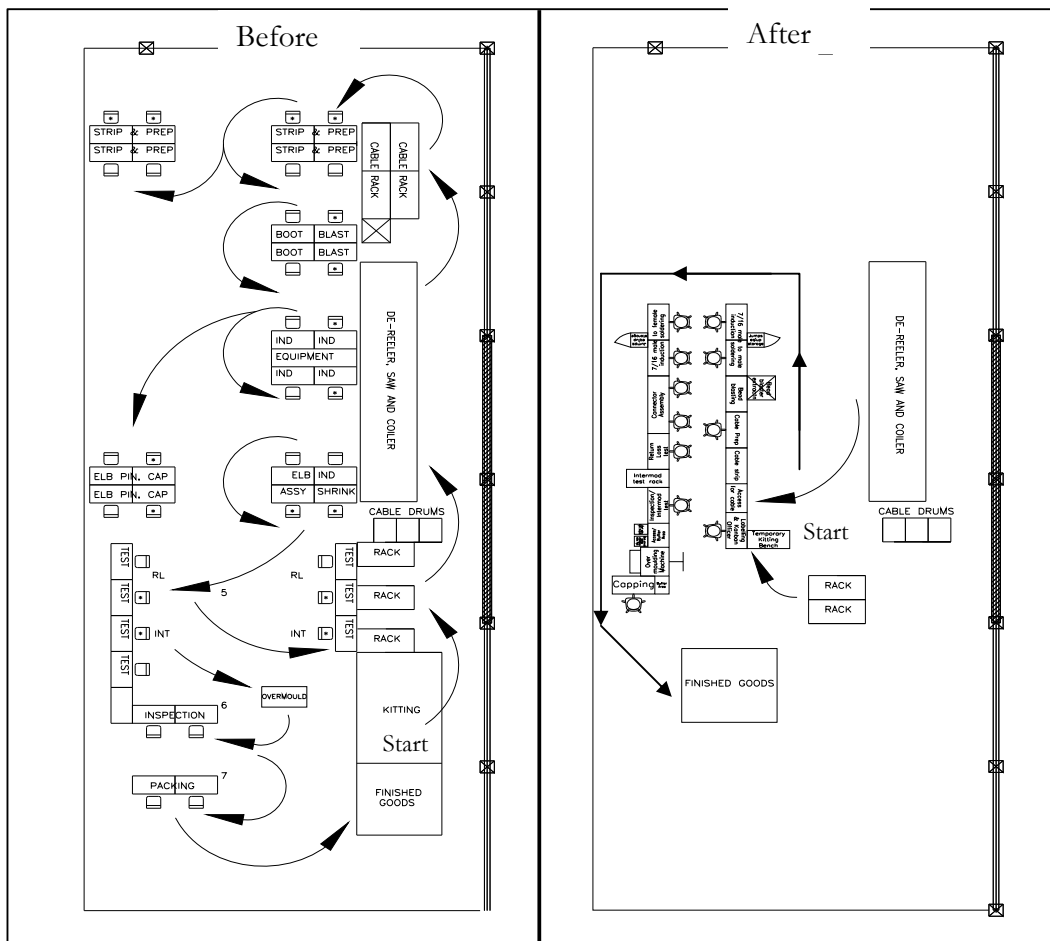


Figure 5.7 Quadrant Connections Assembly Area – Before and After

5.6.7 Step Six – Team to Improve the Process and Implement

The Project Sponsor introduced the need for change, setting the context and financial pressures that Quadrant were facing. It was made clear to all the team that any changes to peoples' roles as a result of the project would not result in any redundancies.

The team went about analysing the current process. As part of this analysis the team carried out a 'Waste Watch' to identify and eliminate the 'non value adding' elements of the process. The wastes identified by the team can be seen in Appendix K.

During the second and third day of support the team redesigned the process to eliminate the waste. This involved eliminating double handling, moving machinery closer together, processing one product at a time and redistributing activities to balance the flow of the product through the process.

5.6.8 Step Seven – Measures of Performance

In direct comparison, the cycle time to produce the jumper cable was reduced from ten minutes to six minutes, with a reduced number of operators; down from fifteen to eight.

In addition to the above direct comparison measures, the following were also identified by the team:

- Lower levels of WIP – the company estimated this to be a 10% reduction.
- Rejects reduced from 0.15% to 0.05%. Due to increased levels and speed of feedback; products are made one piece at a time so if errors occur the process can be stopped before more products with errors are manufactured.
- Distance the product travels during the process reduced 115m to 22m
- Time from receipt of order to packing now only 30 minutes (best) – 83% improvement.
- Floor space usage reduced by 40%. – The new layout can be seen in Appendix L.

These improvements have led to the organisation achieving a productivity increase of 86% and £289,000 of additional value to the business.

A photo of cellular one piece flow in action at Quadrant can be seen in Appendix M.

5.6.9 Qualitative Feedback from the Company

Following the implementation of cellular one piece flow, a sample of those involved in the implementation were interviewed. Those interviewed were; the Personnel Director (Project Sponsor), the Manufacturing Director, the Section Leader and a Team

Member. In addition to the quantitative measures recorded (Section 5.6.8), the following comments and observations were made by those interviewed:

- Subsequent to the implementation there was an increase in motivation and ideas for improvements coming from the team. Similar to the Autoglym case study, it was felt this was attributable to the way that the implementation had been carried out, i.e. that the team had been involved, and felt empowered, to make suggestions of further improvements. After the implementation the team kept an ‘issues and ideas board’ next to the cell to record daily and issues and improvement ideas. There was slight concern from the Manufacturing Director that the team would change things without his knowledge.
- Again, similar to the Autoglym and Delta case studies, all those interviewed said they thought the Lean training and simulation were essential in getting understanding and buy in to cellular one piece flow. The Project Sponsor felt that the training could be rolled out to all employees. However the Manufacturing Director commented that he didn’t think cellular one piece flow was appropriate to all areas of the organisation.
- The team member commented that it had been a entirely enjoyable experience.

The following is a direct quote from a Team Member interview.

“We have designed the way our work works and it was a thoroughly enjoyable experience. We have improved performance so management are happy and we are happy as we are now more of a team” – Delta – Jumper Cable Team Member.

5.6.10 Summary of the Quadrant Case Study

The implementation of cellular one piece flow at Quadrant Delta was a success. The goals set out by the company of raising productivity and increasing flexibility were achieved. The qualitative feedback from the company, and those involved in the case study, was very positive.

The manufacturing process was changed from parts being produced, and subsequently stored, in part finished batches, to a team working in a cell where products flow in a series of one to a fully finished product. Operators now have visibility of what is happening at other stages of the process and are able to work on any part of the process if a bottleneck occurs. There has been a reduction in WIP and space used.

The implementation of cellular one piece flow at Quadrant was carried out over three days split over a three month period.

5.7 Cross Case Comparison

Table 5.2 presents an overview comparison of the three case studies. All measures were substantiated by the organisations.

Measure/Indicator Organisation	Productivity	Labour saving	Floor Space*	WIP	Comments from Organisation
Autoglym	101%	£101k	-	<20%**	Positive feedback/experience
Delta	16%	£233k	70%	<50%	Mixed feedback/experience. Uncomfortable process
Quadrant	86%	£289k	60%	<10%	Positive feedback/experience

Table 5.2 Cross Case Study Comparison

* - Percentage of original floor space used

** - This is an estimate and did not affect the overall company stockholding – as the stock products were supplied internally.

All of the case studies were a success. They each achieved the aims as set out by the individual organisation and in all cases cellular one piece flow was achieved. Each of the case studies are further discussed and compared below. The observations, reflections, and learning in this section were formed with input from the MAS-East team. This input was gained through a half day session, facilitated by the author, in which the process and outcome of each case study was presented, followed by a group discussion.

5.7.1 Autoglym

Autoglym was the first case study. The summary of the achievements are:

- Productivity increased by 101%.
- An annual labour cost saving of £101,000.
- Work in Progress (WIP), both within the process and waiting to supply the process, was significantly reduced.
- There was an increase in motivation and ideas for improvements now generated by employees.

The implementation of cellular one piece flow at Autoglym went very smoothly. Indeed, comments back from the organisation were that the implementation could have been achieved more quickly.

Key observations and reflections were:

- The cross functional team was small, but had all the key members of staff. – This was reflective of the process being a small and discrete area.
- The product was relatively new to the organisation, as was the forming of the team. – This meant it didn't have any history or ingrained way of working, essentially it was a blank canvas.
- The leadership of the implementation, in the Manufacturing Director and Manufacturing Manager, were both experienced in Lean and fully engaged and supportive of the process. – This led to a high level of commitment to make it work.
- The organisation had a history of continuous improvement – walking around the factory this was very apparent with the team boards, which displayed measures of output and productivity. – This 'improvement culture' meant change and improvement was the norm, so was easily received and embraced by the team.
- The Lifeshine kit was essentially a hand assembly process, with no machine tools required, only benches. – This meant it was very quick and easy to change and test new layouts.

5.7.2 Delta

Delta was the second case study. The summary of the achievements are:

- Productivity increased by 16%.
- £233,000 growth in value added.
- 30% reduction in floor space.
- Increased flexibility to cover staff absence.

The implementation at Delta did not go as smoothly as the Autoglym implementation. This was supported by the feedback from the organisation being mixed.

Key observations and reflections were:

- The Managing Director at Delta was initially reluctant to act as Project Sponsor, because of other calls on his time. – This meant he was never really fully engaged in the process.
- The implementation team at Delta was much bigger than the implementation team at Autoglym. – This meant that it was much more difficult and time consuming to get consensus and agreement.
- Because the team was quite large, they were split into two when working on the implementation. – This had the benefit that work could be carried out in parallel but the negative effect was that the two teams didn't always know what the other was working on or agree with the proposed solutions.
- Of the implementation team there were two or three very outspoken, and often negative, members that overshadowed others contributions.
- Delta didn't have any previous history of team based approach to improvement. – The approach of a team, from different levels of the organisation, coming together to collectively solve a problem was something completely new. It was quite uncomfortable for a few of the team members.
- The Production Engineering Manager very clearly wanted the implementation and team based approach to be a success. The Manufacturing Manager clearly had reservations. The dynamics between the two were at times counter-productive to progress and a distraction.

5.7.3 Quadrant

Quadrant was the third and final case study. The summary of the achievements are:

- Productivity increased by 86%.
- £289,000 growth in value added.
- 40% reduction in floor space.
- Lower levels of WIP.
- Time from receipt of order to packing reduced to 30 minutes.

The implementation at Quadrant, like that at Autoglym, went very smoothly. Comments back from the organisation were very positive.

Key observations and reflections were:

- The product was well established, they had been producing and supplying it to the market for over 10 years. This meant the existing process to manufacture was well established, and on the surface, relatively efficient. – However, a productivity improvement of 86% was still achieved.

- The leadership of the implementation, provided by the Manufacturing Director, had both experience in Lean and was fully engaged and supportive of the process. – This led to a high level of commitment to make it work.
- Similar to Autoglym, the organisation had a history of continuous improvement. - This ‘improvement culture’ meant change and improvement was the norm, so was easily received and embraced by the team.
- The Jumper Cable manufacturing process required significant, specialist machine tools, however these were relatively easy to move. There was one large machine tool that required foundation bolting to the floor, so to avoid having to move this the cell was orientated around its existing position. – This meant it was relatively quick and easy to change and test new layouts.
- The implementation team at Quadrant (10) was of a similar size to the implementation team at Delta (12). However none of the team issues which arose at Delta arose at Quadrant – This suggests that team size alone is not a inhibitor to a smooth implementation.
- Because the team was quite large, they were split into two when working on the implementation. However each team ‘checked in’ with the other every hour to check progress and alignment. – This suggests that as long as there is good, regular communication then a large team can be split into two teams and work successfully.
- The implementation team were very collaborative and hierarchical status didn’t constrain an individual’s ability or confidence to input. – This meant that the team had a strong collective unity.

5.7.4 Similarities Across all Case Studies

All three of the implementations were completed within three months. The author believes this shows that implementation and improvements through cellular one piece flow can be achieved and realised quickly. However the author also believes that implementation could be even quicker. Reflection and interviews with the teams after the implementations were completed identified that there was considerable ‘dead time’ when implementation work was not carried out but could have been to shorten the overall time.

All of the case studies were taken up by the organisations to help reduce costs. Only Autoglym were in the enviable position of needing to increase output as a key driver for implementing cellular one piece flow. In all cases, reducing costs, or increasing value add were achieved. This suggests cellular one piece flow is a legitimate approach to reducing costs.

All three of the case studies benefited from the use of quick and cheap mock ups of jigs, storage and other equipment, to test suitability.

5.8 Conclusions

In all three case studies cellular one piece flow was successfully implemented. This was achieved with minimal costs. This supports the Gunasekaran (2000) study, which concluded Lean strategies need minimal financial investment.

The same Gunasekaran (2000) research did however identify that substantial investment is required in changing work culture. The issues at Delta, and conversely the smoothness of Quadrant and Autoglym suggest that organisational culture and the people elements are crucially important. The author found that technical, 'hard issues', for example moving machines, were relatively easy to identify. Once identified it was again relatively easy to make a decision on whether the issue could be resolved, in this example whether the machine tool could be moved. If all the technical issues could be resolved then the implementation could take place. However 'soft issues' were much more difficult to identify and much more difficult to resolve in a clear cut way. Culture and human factors are also cited as being important by Hyer et al (1999) and Park and Han (2002). Hyer et al (1999) believe if too little attention is given to the human dimensions in cell design and implementation, implementation will often fail. Whilst, in their empirical study, Park and Han (2002) show that human and organisational factors, specifically training and education, information, teamwork skills and supervision, play a central role in cellular manufacturing implementation.

Vavra (2008) found that human and organisation culture issues dominate when compared with tools or technical issues. Chakravorty and Dulaney (2010) also found that effective management of human aspects are critical for improvement initiatives.

Yauch and Steudel (2002) identified eight key cultural factors that impacted on the implementation of cellular manufacturing. Seven had a negative impact and one had a positive impact.

Negative Factors

- 1) Under-organisation - the organisation lacks systems, policies and procedures.
- 2) Avoidance - avoidance of decision making, taking action or risks
- 3) Lack of respect and trust - between employees and management
- 4) Crisis Urgency - only a crisis stimulates action
- 5) Complacency - satisfaction with the status quo
- 6) Rigid Group Boundaries – organisation members create barriers between groups
- 7) Overemphasis on Core Activities – employees solely focus on doing the current routine and lack time for improving processes and systems

Positive Factors

8) External customer focus – The organisations true mission is to satisfy their customers. (Yauch and Steudel 2002)

Factor 3, lack of respect and trust, and factor 5, complacency, were especially prevalent in the Delta case study.

In considering the previous research and the case study research carried out here, the author supports the view that ‘soft issues’, such as organisation culture and people issues were a key issue to be considered prior to implementation of cellular one piece flow.

6.1 Introduction

This Chapter brings together all of the different strands of the research in a discussion. Firstly, Section 6.2 gives an overview of the research, including the area covered by the research, the research conducted and the outputs. Section 6.3 offers reflection and learning from the review of East of England manufacturers. This process of reflection and learning is continued to the literature review (Section 6.4 and Section 6.5) and the case studies (Section 6.6). A comparison of this research with previous research is offered in Section 6.7. Section 6.8 describes how the approach used in the case studies was validated, and endorsed as the new standard approach, by the MAS-East team. Following the reflection and learning, and validation by MAS-East a final implementation process is presented in Section 6.9. The applicability and limitations, Section 6.10 and Section 6.11 respectively, are discussed before a chapter conclusion.

6.2 Overview of this Research

This section provides an overview of the research. It outlines the research area, describes the research objectives and research outputs.

6.2.1 Research Area

Manufacturing is vital to the United Kingdom's economy. In work presented earlier in this Thesis it can be seen that:

- UK manufacturing employs between 2.8 million to 4 million people, with many more reliant on manufacturing indirectly through supply chain and other services (Section 1.4.1). Manufacturing contributes to between 13% to 20% of the United Kingdom's GDP (Section 1.4.1).
- UK manufacturing productivity is significantly worse than that of our traditional global competitors (Section 1.4.2).
- Small and medium sized enterprises play a significant role in both national and regional economic development and prosperity (Section 1.4.4).
- Small to medium sized organisations typically have lower productivity than larger organisations (Section 1.4.4).
- Manufacturing employment has fallen dramatically over the last 20 years. However this overall decline masks a significant shift in the share of employment in manufacturing to smaller organisations. Manufacturing employment in smaller manufacturing organisations has declined far less than in

larger organisations, strengthening the importance of smaller manufacturers (Section 1.4.4).

- The East of England region relies on the manufacturing sector for its economic prosperity (Section 1.4.5).

It can be concluded from this evidence that manufacturing is important to the economic prosperity, both nationally and regionally for the East of England. SMEs account for a significant portion of manufacturing, both in terms of number of employees and value of output. UK manufacturing, and SMEs particularly, face challenges, and opportunities, to improve productivity and performance.

6.2.2 Research Conducted and Research Outputs

The objectives of this research, as presented in Section 1.6, were:

1. Review whether SME manufactures in the East of England have opportunities to improve productivity and performance.
2. Carry out a literature review to identify whether cellular one piece flow delivers improved productivity and performance.
3. Develop and test a process for the rapid implementation of cellular one piece flow in SMEs

All of these objectives were met:

- The first objective was met through the review and analysis of MAS-East visits to manufacturers in the East of England. This analysis was presented in Chapter 2 and is discussed further in Section 6.3
- The second objective was met through a literature review. This review was presented predominantly in Chapter 2 and Chapter 4. It is discussed further in Section 6.5.
- Finally, the third objective was met through the development of a process, based on previous research identified in the literature review, for implementation of cellular one piece flow. This was first presented in Section 4.7. It was then tested with the three case study organisation (Chapter 5). This is discussed further in Section 6.6.

The outputs (deliverables), resulting from these objectives, as described in Section 1.7 are:

- A literature review of the implementation of cellular one piece flow.
- A process, founded on previous research, for implementing cellular one piece flow.

6.3 Discussion on the Review of East of England Manufacturers

The author was fortunate to be able to benefit from the data collected through the work of MAS-East. Analysis of this data enabled a view to be taken on the first research objective: Review whether SME manufacturers in the East of England have opportunities to improve productivity and performance. The MAS-East data set contained records of over 400 visits to manufacturing companies in the East of England during the period 2003-2004. These company visits consisted of a MAS-East Manufacturing Specialist spending a full day with the organisation, observing, examining evidence and discussing performance and opportunities. The records from these visits provided the author with a rich picture of information, the summary of which was presented in Section 2.3. The conclusions of this analysis were quite compelling: in every company visit opportunities to improve were identified and agreed by the organisation. This analysis presented the case, and was the principle stimulus, for doing this research. Without the work of MAS-East this information would not have been available.

Whilst the author believes this provided a strong evidence base for carrying out the research it is not without its weaknesses. There are limitations around the applicability and generalisability of this information. The data was drawn from visits carried out by MAS-East. These visits would typically be initiated by organisations requesting a Manufacturing Specialist visit. In discussion with all the Manufacturing Specialists the organisations that requested visits were typically from two groups of organisation:

- Organisations that were struggling to survive and needed urgent support to save costs.
- Organisations that were financially and operationally stable that had a culture of proactive improvement.

Therefore, the data is taken from a sample of organisations that may not accurately represent all manufacturers in the East of England. Further, comprehensive, research and classification into groups, of manufacturers in the East of England would be useful.

Whilst these weaknesses are acknowledged the author still believes that a sample size of over 400 organisations provides a strong message and catalyst for change.

6.4 Discussion on the Process of Carrying out the Literature Review

The literature review informed and provided a foundation for the case study research. Therefore it was essential that this literature search be robust. With uncertainty over how much previous research had been carried out, and how many literature papers should be identified, a robust process was required to ensure the comprehensive identification of published work. The approach and process used to carry out the literature review (Section 2.2) details how this was carried out. Whilst the author is satisfied that this was achieved, there were lessons learnt. The author considers the overarching three phase approach to the literature review to be a good approach. The first two phases of a background review on SMEs and an initial literature review of cellular one piece flow were carried out successfully and relatively easily and quickly. However the third phase; a detailed and focused search on implementation of cellular one piece was time consuming and at times very unproductive. This was because the author did not initially have a thorough process for searching and recording literature searches. The key lesson here was that a robust process, following a systematic approach, to identifying literature is key to ensuring a through outcome. This should, ideally, be thought through and agreed prior to carrying out the work.

6.5 Discussion on the Literature Review

The literature review split into two parts;

- The first part explained and examined one piece flow and cellular manufacturing. This was presented in Chapter 2. This is discussed in Section 6.5.1.
- The second part examined previous research on implementations that had been carried out. This was presented in Chapter 4. This is discussed in Section 6.5.2

6.5.1 Discussion on One Piece Flow and Cellular Manufacture

The industrial sponsor of this work, MAS-East, set the research question ‘How can cellular one piece flow be rapidly implemented in SMEs to bring about improved productivity and performance?’ The stimulus for asking this question was the Director of MAS-East belief that the practice of cellular one-piece flow had received little formal attention. The first aim of the literature review was to test this assumption. The literature review identified an extensive collection of literature on cellular manufacturing but none explicitly on cellular one-piece flow. The MAS East Director’s assumption was validated and his view affirmed. A research gap was identified.

The second assumption, inherent in the research question, was that cellular one piece flow **does** bring about improved productivity and performance. This was also tested through the literature review. Cellular manufacture is not new and numerous previous

research studies have identified its significant impact and spread within manufacturing organisations (Spraggett et al 1995) (Johnson and Wemmerlov 2004) (Waterson et al 1999) (Boughton and Arokiam 2000). All of the previous research demonstrated improvements were made through cellular one piece flow. This assumption was therefore validated.

In addition, a primary motivation and intention for carrying out this research is to stimulate SMEs to adopt and obtain the benefits of Lean manufacturing techniques then combining cellular manufacture and one piece flow is an ideal place to start. Previous research demonstrated:

- Cellular manufacture is central to Lean manufacturing. Boughton and Arokiam 2000) (Park and Han 2002) (Da Silveira 1999) (Wemmerlov and Johnson 1997).
- Layout revision, which is central to cellular manufacture, is the optimum starting point for adopting Lean (Gunasekaran and Lyu 1997) (Brown and Inman 1992)
- Cellular manufacture is a low risk, low cost first step. (Gunasekaran et al 2001) (Baker and Maropoulos, 2000) (Shayan and Sobhanallahi. 2002) (Gunasekaran et al² 2000) (Chambers and Nicholson 2000).
- One piece flow significantly reduces WIP
- To achieve one piece flow, and improve productivity and performance, an organisation will have needed to have completed the process of cellular manufacture. One piece flow is considered the ultimate, and most difficult, step in achieving a Lean process (Miltenburg 2001) (Lander 2007)

6.5.2 Discussion on the Implementation of Cellular One Piece Flow

The factors that were important when considering the previous research on the implementation of cellular one piece flow were:

1. The author's intention that **this research act as a stimulus** to others into adopting cellular one piece flow.
2. That the cellular one piece flow implementation was as quick as possible – **rapid implementation.**
3. That **this research be based on previous research**, wherever possible. – The intention here was that if this research built on a body of evidence it would help to get a critical mass and 'tipping point' – further strengthening the case for change for others to adopt cellular one piece flow.

These factors are further considered in the next section.

6.5.2.1 This Research act as a Stimulus

Chapter 4 examined previous research on the implementation of cellular manufacture. This identified that approaches to cellular manufacturing could be classified into two distinct approaches; pragmatic and optimal. It is the author's intention that this research stimulate others into adopting cellular one piece flow. Therefore a pragmatic approach was taken.

Of the previous research that was pragmatic many authors advocate a participatory and integrative approach with a multi disciplinary team from within the company. This inclusive approach was chosen as it would enhance the chances of cellular one piece flow being sustained after the implementation was finished.

Barriers to the uptake of cellular manufacturing were presented in Section 2.4.3. Boughton and Arokiam (2000) identified that organisations needed to be medium to high volume producers to benefit from cellular manufacture. – All of the case study organisations could be categorised as medium volume produces. Therefore this research does not test this view. However, their research identified 'lack of sufficient space' as the most commonly cited anticipated difficulty, and barrier, to the implementation of cells. This research has demonstrated, in two of the three case studies, that less floor space is required.

The volume of products produced by an organisation is also cited by Johnson and Wemmerlov (2004) as one of their seven factors in preventing organisations from implementing cells. What is perhaps most interesting from their research is that 'previous cell experiences weren't positive' was the lowest scoring factor – and therefore it could be concluded that previous experiences of implementing and using cells were generally successful and positive.

6.5.2.2 Rapid Implementation

Most of the identified previous research did not indicate the length of time taken to implement cellular manufacture. – Most described the length of time of the research study, which in some cases was up to six years (Chakravorty and Hales 2004). The two exceptions to this were the Da Silveira (1999) study and Van Rhijn et al (2005) study, which were implemented over 15 and 9 months respectively.

SMEs have been seen to respond to rapid improvements (Nelder et al 2000). This was also the challenge laid down by the industrial sponsor. Therefore to stimulate other SMEs, the aim was for each of the three case study implementations were completed within a three month period.

6.5.2.3 This Research be Based on Previous Research

The lack of research in implementing Lean manufacturing techniques, such as cellular one piece flow, and the lack of clarity regarding how they can be implemented, has led to SME not fully exploiting the benefits (Achanga et al. 2004).

The literature review identified different approaches and models used for the implementation of cellular one piece flow. The models used in previous research are all slightly different; however they did have some similar themes. These themes were identified and any that featured in two or more previous research studies, with the exception of 'rewards and compensation', were used as part of the process for this case study research.

6.6 Discussion on the Case Studies

Three organisations were selected to test the implementation process developed by the author. All three organisations were from the Regional Development Agency priority sectors; automotive, electronics and telecommunications. This was to ensure that the research addressed an immediate need and aligned with regional strategy.

V-A-T analysis was used to categorise each of the organisations in terms of how their production processes. All three organisations can be seen to be 'T' type organisations. This focus on 'T' type organisations strengthens the applicability of cellular one piece flow for other 'T' type organisations.

6.6.1 Discussion on the Implementation Process

The implementation process, as presented in Section 5.1, was:

Process for implementing Cellular One Piece Flow

- 1) Identify Aims / Goals.
- 2) Form Cross Functional Team.
- 3) Get measures of current performance.
- 4) Analysis of the process.
- 5) Training in Lean.
- 6) Improve the process, eliminate Non Value Adding activities and implement.
- 7) Get measures of performance.

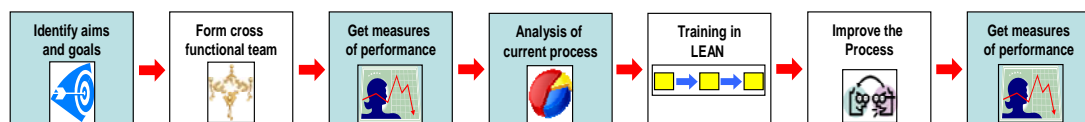


Figure 5.1 Process to Implement Cellular One Piece Flow

6.6.1.1 Reflection and Learning: Step One – Identify Aims and Goals

Initial meetings were held with each of the case study organisations to identify the project area to work on. In all cases the project area chosen was identified as the area that the organisation thought would deliver the most benefit from adopting cellular one piece flow. Once the project area had been agreed the aims and goals for the implementation were discussed and agreed with senior managers from the case study organisations. The purpose of this stage was three fold. Firstly, it was to identify and agree the criteria to which the implementation would be deemed a success, so that at the end of the implementation a clear measure could be taken to assess success or failure. Secondly, it was to provide a framework within which decisions could be taken during the implementation. Thirdly, it was to provide open and transparent objectives for the implementation team.

During the process of carrying out the research it became apparent that a fourth aspect of step one was also proving very useful. During the discussions with senior managers reasons for undertaking the implementations (aims and goals) were always discussed. These reasons, whilst known to senior managers, were not well known to other employees. Simply communicating and explaining the reasons in an open way gave a strong motivation to the implementation teams.

However, as the Delta case study showed, care needs to be taken when explaining these to staff as it can make them nervous about possible redundancies. Following the Delta case study senior managers at Quadrant were asked to make it clear that no redundancies would result from any labour savings made through the implementation.

Setting the aims and objectives is a key first stage as it sets the direction and ambitions for the implementation.

6.6.1.2 Reflection and Learning: Step Two – Form Cross Functional Team

The constituent members, both in terms of numbers and job roles, varied to at least some degree for all three implementations. There were only two key requirements for all of the implementations:

1. At least one employee from every part of the process to manufacture was represented in the implementation team.
2. A senior manager was part of the implementation team to act as ‘Project Sponsor’.

It was originally intended that the senior manager ‘project sponsor’ would be present throughout the implementation. However during the first implementation at Autoglym two issues became apparent. Firstly, with many calls on their time it was difficult for a senior manager to commit to spending the full day of each of the implementation days

working on the implementation. On many occasions the senior manager was called away to deal with other issues. This distracted the team and momentum was lost. However it did lead to a valuable discussion with the team and identification of the second issue; the senior manager being present sometimes inhibited the openness and creativity of the other team members. Upon discussing this with the team they stated that they felt much more conscious of what they were saying and of appearing critical of ideas or of proposing ideas that might be considered unfeasible or inappropriate whilst the senior manager was present.

For these reasons, in subsequent implementations the Project Sponsor was asked to only periodically visit the team during the day and also to be present for the last half hour of each day to listen to feedback and offer support.

However, Delta, which followed the Autoglym case study, undoubtedly suffered from a lack of management buy in and commitment. In their research study into critical success factors for lean implementations in SMEs Achanga et al (2006) reported that leadership and management commitment is the most important factor. Therefore in the last case study implementation it was made clear to the Project Sponsor that although they would not be required all day during the implementation, their availability and support was essential.

In their study of 150 organisations, Khan and Bali (2007), found shop floor employees were willing to learn and be involved in company wide improvement initiatives. However the shop floor employees did voice concern regarding any possible redundancies which would result from the improvement implemented, saying that this could cause fear, resentment and resistance to change. The findings of the Khan and Bali research are supported by this research.

6.6.1.3 Reflection and Learning: Step Three – Measures of Current Performance

This step was the first time the implementation team formally gets together. The first morning of the first implementation with Autoglym did not go smoothly. Autoglym had an outstanding order to complete before some of the team members could be released to work as part of the implementation team. This issue could have been eliminated if better planning had been carried out. An implementation checklist was developed to check all necessary arrangements, facilities and details of the implementation had been covered and were in place. The implementation checklist developed can be seen in Appendix H.

For each of the three implementations measures of output were taken for two different products. This was to enable a direct before and after comparison to be made. This was a very simple step that proved to be very powerful. Comparison of performance directly before and directly after the implementation meant that there were no other factors, apart from the implementation of cellular one piece flow, that could have affected the change in performance. However, a weakness of only taking a measure of

performance immediately after the implementation is that it does not assess the sustainability of the improvements.

6.6.1.4 Reflection and Learning: Step Four – Analysis of the Current Process

In each of the implementations the team carried out a detailed process map. Process maps are discussed further in the following section. The teams worked together on this which had a number of benefits:

- Because there was a representative of each stage of the process in the team, there was always at least one ‘expert’, who knew the detail and reality of what happened and any issues.
- Because the rest of the team were all involved it meant they could see and understand what happened in the stages of the process in which they were not directly involved in. This enabled them to get a better understanding of the whole process and also question why things happened. - A good example of the benefit of this was with Delta implementation. The process for assembly of the beacon prior to the analysis of the current process and implementation of cellular one piece flow, as detailed in Section 5.5.6, was to lace base on the bench (step 2) prior to adhering the internal label (step 3). However when the team reviewed this process it was identified that it was much better and easier to adhere the label before lacing the base as the wires didn’t get in the way. Lacing the base prior to adhering the label was the way it has always been done and no one had questioned it before.

The Delta implementation also highlighted the risk and potential issue of splitting the implementation team.

6.6.1.4.1 Process Maps

After a particular product or area has been identified for improvement, the next step is to determine what is involved in the manufacture of that particular product. (Chen et al 2010). Process mapping shows the sequence of tasks, information, materials and personnel required to make a particular product. Process maps are usually offered in either tabular form or as a flowchart. The most widely used and accepted is the flowchart (Nash and Poling 2009). Process mapping is used to document the ‘current state’ i.e. all the tasks and what currently happens in a process, so that opportunities for improvements can be identified. It also helps to gain a collective shared understanding of the process (Gregory 2006).

According to Monden (1998), any task in a manufacturing process can be classified into one of three categories: incidental work, value added work, and muda (waste). Incidental work is task such as inspection; that do not add value to the product but a necessary part of the system to produce the product. Value added work adds value to the work and directly contribute to changing or making the product the customer

wants. Muda, Japanese for waste, are tasks that do not add value, i.e. directly contribute to the changing or making of the product, or contribute to the system required to produce the work. Another way to look at waste is that it is anything a customer would not be willing to pay for.

Once the waste in a process has been identified it can be removed. A 'future state' process map is drawn to show what the new process, with the waste removed, looks like. By improving processes, through identifying and removing waste, organisations can improve its internal effectiveness, efficiencies and productivity (Kumar and Phrommathed 2006) (Imai 1997)

6.6.1.5 Reflection and Learning: Step Five – Training in Lean

The Lean training and especially the demonstration of cellular one piece flow through the simulation worked extremely well in demonstrating, in a practical way, the benefits that could be achieved. In subsequent discussions with all of the implementation teams they all stated that the demonstration through the simulation 'made it real' and 'a light bulb came on'. If the implementation and improvements are to be sustained and the team is to be enabled to go on to make further improvements independently, then it is absolutely crucial they really understand the concept of cellular one piece flow. The simulation undoubtedly gave this understanding.

During the first implementation case study at Autoglym it became apparent, and was voiced by the Autoglym implementation team, that it would have been more helpful to have done the Lean training and simulation prior to Step 4 - Analysing the Current Process. For both subsequent case studies at Delta and Quadrant Step 5 – Training in Lean was carried out prior to Analysing the Current Process. This meant that the process had changed to:

- 1) Identify Aims / Goals.
 - 2) Form Cross Functional Team.
 - 3) Get measures of current performance.
 - 4) **Training in Lean**
 - 5) **Analysis of the process.**
 - 6) Improve the process, eliminate Non Value Adding activities and implement.
 - 7) Get measures of performance.
- ← Order of steps switched

6.6.1.6 Reflection and Learning: Step Six – Team to Improve the Process and Implement

As the facilitator, improving the process was the most difficult step. It was a fine line between being a team member and challenging the other team members in improving the process. It was also difficult to not interject with the solution before the team had an opportunity to work through the issue themselves. Chakravorty (2009) believes the facilitator should exercise caution in not hastily offering solutions to problems. If the

workers come up with solutions they have ownership and there is a higher chance of the improvements being sustained.

Some of the implementation team members found the change process quite unnerving. The changes to the process were perceived as leading changes to the organisations requirements for them as employees. One team member in particular became quite distressed with the changes to the process and how it could affect her job. As a result of this in the subsequent implementation at Quadrant Connections the project sponsor was asked to state at the start of implementation that no redundancies would result in any of the changes made.

Feedback from the team members after the Delta implementation was that some of the staff not involved in the implementation were inquisitive and unsure about what was being carried out and why. This could potentially lead to misconceptions and damaging rumours. Therefore as part of the next implementation at Quadrant the team would do a briefing or presentation to other members of staff at the end of each day.

6.6.1.7 Reflection and Learning: Step Seven – Measures of Performance

Just as measures were taken before the implementation, measures of output were taken, for the same two different products, after the implementation. This proved to be incredibly powerful in demonstrating the direct tangible improvements as a result of implementing cellular one piece flow. Because the measures were taken immediately prior to and immediately after implementation other factors which could influence the outcome, and performance, were limited

6.7 Comparison of Case Study results with Previous Research

Table 6.1 presents the achievements from the three case studies of this research with the quantitative achievements of research identified through the literature review

Measure/Indicator	Productivity	Labour saving	Floor Space % reduced	WIP	Scrap/rework % Improvement	lead time % Improvement
Organisation / research						
Autoglym	101%	£101k	-	<20%**	0	40%
Delta	16%	£233k	70%	<50%	10%	33%
Quadrant	86%	£289k	60%	<10%	60%	83%
Hyer (1999)	-	-	-	-	35%	50%
Chakravorty & Hales (2004)*	-	-	-	< 86%	53%	49%
Da Silveira (1999)	-	-	44%	< 92%	40%	80%
Wemmerlov & Johnson (1997)**	-	-	-	48%	-	50%
Van Rhijn (2005)	44%	-	44%	-	-	46%

Table 6.1 Quantitative Achievements of Cellular One Piece Flow

* Results taken one year after implementation.

** Average results from a survey of 46 organisations.

There are only a limited number of metrics that were common to the majority of studies and only lead time improvement was common to all. This could be for a number of reasons, including different organisations having different priorities, or drivers, for implementing cellular one piece flow.

When the case studies of this research are compared to the case studies of previous research they appear relatively unspectacular. The outcomes appear to be broadly similar, for example the lead time improvement achieved in this research ranged from 33% - 83%, in previous research it ranged from 46% - 80%. This could indicate that implementation of cellular one piece flow consistently delivers significant improvement.

However, research by Olorunniwo (1997) concluded that implementation can be judged to have been highly successful if it shows an improvement of greater than 50% in Delivery Response (throughput time can be used as a surrogate measure) or greater than 25% improvement in Quality / Costs measure. Only the Quadrant implementation fulfils these requirements.

Previous research showed the quickest implementation time was 9 months (Van Rhijn et al 2005). This research has implemented cellular one piece flow, in each of the three organisations, in 3 months.

6.8 Validation by MAS-East & Implications for future MAS-East work

Following the three case study implementations a workshop was held with the MAS-East Manufacturing Specialists to discuss and validate the process for implementation. This is described in Section 5.7. Further to this, a session was held with the MAS-East team to discuss all the strands of the research, as discussed in this chapter. This session covered all aspects of the research, from initial conception, through the literature review and to the case study implementations. Following this session it was agreed that the process shown in Figure 6.1 (Section 6.8) would be the standard MAS-East approach for all subsequent implementations of cellular one piece flow.

A key consideration in the discussions with the MAS-East team was the sustainability of any changes after any external support had left. Human factors and organisational culture were identified during this research, and previous research, as being key issues in achieving successful implementation. Human factors and sustainability are interlinked, as without human buy in sustainability will be lost. Therefore the way in which cellular one piece flow, and other lean tools, are implemented needs to involve employees from the very beginning, is key to sustainability. This is supported by Seppala and Klemola (2004). In addition to this Rhijn et al (2005) found that five out of six operators were more satisfied with the conversion from batch to cellular single piece flow. Gunasekaran et al (2001) found that workers had improved morale. Wemmerlov and Johnson (1997) believe cells represent sociological units conducive to

teamwork. In their research 73% of the responding 33 organisations believed employee involvement had improved and no organisations indicated a decrease in employee involvement.

The MAS-East team also agreed that Supervisors typically orchestrated the actual changes and can be very influential on other employees. This was supported by Chakravorty and Hales (2004).

6.9 Final Implementation Process

Following the three case study implementations of cellular one piece flow and validation by MAS-East experts the implementation process was revised and is presented below in Figure 6.1.

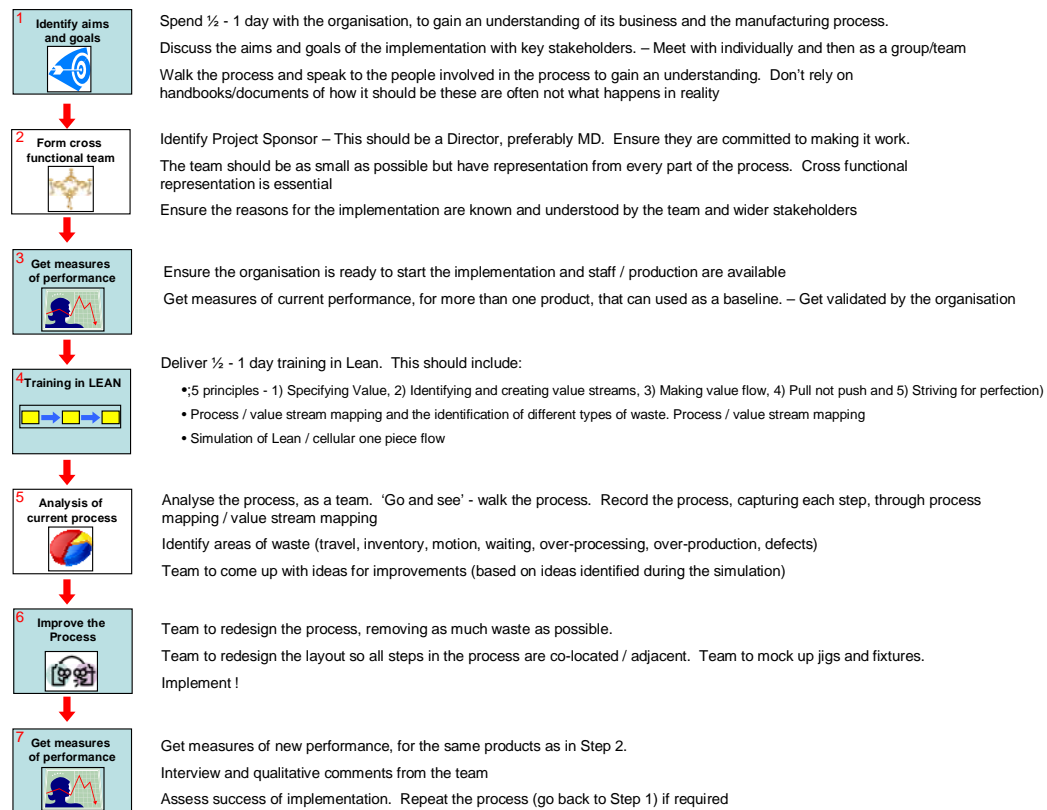


Figure 6.1 Process to Implement Cellular One Piece Flow (Final Version)

6.10 Applicability

All of the case study organisations cited reducing product cost as a reason for undertaking the project. SMEs, unlike larger organisations, do not always have the purchasing power over their suppliers to continually demand price reductions. The view that smaller firms may not hold sufficient influence over suppliers is supported by Temponi et al (1995). Therefore any cost savings on producing finished goods that can be achieved internally, through changes in the process or the way goods are manufactured, are key to reducing costs and profitability.

This can be seen in the Quadrant example where the customer (a large organisation) imposes price reductions on their suppliers. The large organisation can use leverage on suppliers, but SMEs with smaller purchasing have no or limited leverage on their suppliers to reduce the purchase prices to them. Therefore the majority of cost savings need to be found from within the organisations process. Cellular one piece flow is a method of reducing costs that is entirely within an organisation's control.

This is likely to be a similar situation for most SMEs, who will, by definition, lack the volumes purchasing power to solely reducing costs through suppliers. Therefore improvements that can be made to internal manufacturing processes, such as by introducing cellular one piece flow, are potentially applicable other SMEs

6.11 Limitations

There are some factors which are limitations of this research:

- Cellular manufacturing has been advocated as the preferred approach for moderate volume and moderate variety manufacturers (Boughton and Arokiam. 2000). All three of the case study organisations could be called 'medium volume' producers. Therefore the research did not test the implementation of cellular one piece flow on low volume production.
- The case study organisations were deliberately chosen from different manufacturing sectors to show application of cellular one piece flow across a range of companies from a range of sectors. The organisations were from the automotive, electronics, and information and communication technologies sectors. However all three of the processes, improved through cellular one piece flow, within the three different organisations were predominantly 'hand assembly' manufacturing processes. Therefore there were no constraints with moving or modifying large machine tools or other capital equipment. The costs of moving or modifying machine tools or other capital equipment could make the implementation of cellular one piece flow financially unviable. A cost analysis would need to be undertaken prior to the implementation of cellular one piece flow should this be the case. A cost analysis was not carried out as

part of this research. In addition, because the case study organisations did not use numerous machine tools, long tooling changeover times were not an issue. Tooling changeovers have been shown to inhibit the effectiveness of cellular manufacture (Jing-Wen and Barnes 2000)

- The implementation was deliberately carried out over a short timescale. – As previous research cited that SMEs looked for immediate benefits. However there is a danger in that this means there are no longitudinal measures of sustained improvement. Also, even if the gains are sustained, due to the short-term nature of the support for the organisations in implementing cellular one piece flow there is a danger that there has been insufficient time with the organisation to truly achieve the knowledge transfer which would enable them to implement cellular one piece flow independently.
- The outcome and results of the implementations do not take into account the costs, such as lost production on the days when the project team were implementing cellular one piece flow. It is the author's belief that these costs are far outweighed by the results achieved. However, the research would benefit from a form of quantification of the full cost benefit of the work.
- Using V-A-T analysis, all three organisations were the same type of organisation ('T type'). Therefore this limits the applicability to 'T type' organisations.
- The research has inherent limitations, due to the action research approach. The action research methodology involves the researcher being involved as part of the team influencing and deciding the outcome.

These limitations need to be considered, and could help identify future research in this area, however the author believes that the findings are generally applicable.

6.12 Chapter Conclusions

This Chapter brings together all of the different strands of the research in a discussion.

The overview of the research demonstrated that manufacturing, and in particular SME manufacturing, is important to the economic prosperity, both nationally and regionally for the East of England.

A discussion on the main elements of this research; the review of East of England manufacturers, the process for carrying out the literature review, cellular and one piece flow and the implementation of cellular one piece flow and finally the case studies were presented. These were validated by MAS-East Specialist before a final revised process for implementation was presented in Section 6.9.

Finally, the applicability and limitations of the research have been discussed.

CHAPTER 7 CONCLUSIONS

7.1 Introduction

This Chapter provides an overview of the research, summarises the contribution to knowledge and practice, and outlines areas for future work following this research.

7.2 Overview of this Research

The outcome of this thesis could be summarised as:

A practical process for the rapid implementation of cellular one piece flow

SMEs in the East of England have been found, by this research, to have opportunities to improve productivity and performance. Through a literature review cellular one piece flow has been proven, mostly in larger organisations, to improve productivity and performance. The author has developed and tested a process for the rapid implementation of cellular one piece flow in SMEs. The process has been designed to stimulate other SME organisation in following this approach and to enable MAS-East to have a consistent and proven approach in their support to organisations, when implementing cellular one piece flow.

7.2.1 Research Aim and Objectives

The aim of this research was to identify: **How can cellular one piece flow be rapidly implemented in SMEs to bring about improved productivity and performance ?** This aim has been achieved. A process for rapidly implementing cellular one piece flow was developed and tested with 3 case study organisations, with the following results:

Case Study A - Autoglym

- Increased packs per person produced per hour from 9.3 to 18.6 and from 8 to 16.6 in first two products run.
- Productivity increased by 101%
- An annual labour cost saving of £101,000

Case Study B - Delta

- Increased product output from 6.6 to 7.2 and 5.7 to 6.6 per person per hour.
- Reduced floor space required by 70%
- Productivity increased by 16%.
- £233,000 of additional value added to the business.

Case Study C - Quadrant

- Production time to produce product reduced from 10 minutes to 6 minutes, with a reduced number of operators; down from 15 to 8.
- Reduced floor space required by 40%.
- Productivity increase of 86%
- £289,000 of additional value added to the business.

The objectives of this research, as detailed in Section 1.6, have also been met:

- The first objective; **review whether SME manufacturers in the East of England have opportunities to improve productivity and performance**, was met through a analysis of MAS-East visits. This analysis was presented in Chapter 2 and discussed in Section 6.3
- The second objective; **carry out a literature review to identify whether cellular one piece flow delivers improved productivity and performance**, was met through a literature review which was presented in Chapter 2 and Chapter 4 and discussed in Section 6.5
- Finally, the third objective; **develop and test a process for the rapid implementation of cellular one piece flow in SMEs**, was met through the development of a process, based on previous research, which was then tested with 3 case study organisations. The three case studies are presented in Chapter 5 and discussed in Section 6.6.

7.3 Contribution to knowledge and practice

Cellular manufacture is not new and numerous previous research studies have identified its significant impact and spread within larger manufacturing organisations. However the adoption of cellular manufacturing in SMEs has been less well researched. This research adds to the existing body of evidence in this area. In addition this research has developed and tested a process for concurrently implementing cellular manufacture and one piece flow in SMEs. The author could not find any previous research in this area.

This research was carried out in collaboration with an industrial sponsor: MAS-East. The outcome of this research was a process for the rapid implementation of cellular one piece flow. The process developed by this research has now been adopted by MAS-East as their standard approach in supporting any organisation with the implementation of cellular one piece flow.

SMEs represent over 99% of businesses, contribute more to UK turnover and employment than large organisations and yet typically have lower productivity than larger organisations. In addition to this the contribution of SME manufacturing organisations is growing, relative to larger organisations. Therefore the potential

impact of this research in stimulating SME in adopting Lean manufacturing techniques could be dramatic, both to the individual organisations and collectively to regional and national economic prosperity.

This research also adds to the existing body of evidence that the implementation of cells improve productivity and performance. - All of the identified previous research showed cells improved productivity and performance, this research supports that finding.

7.4 Future Work

The approach for this research has been for quick and short timescale implementations to prove rapid improvements can be made. However this approach would benefit from follow on over a period of time to assess sustainability of the improvements made. In addition to this follow on over a period of time would give the benefit of being able to assess whether there was sufficient time spent with the organisations to truly act as a catalyst for them to make further improvements independently.

Section 6.3 discussed the review of manufacturers in the East of England. In this section it was identified that a useful piece of future work would be to undertake a more comprehensive review and audit whether all manufacturers in the region have opportunities to improve productivity and performance. Furthermore, as MAS is a national initiative, there would be opportunities to expand this research throughout England.

The process developed by the research is now the standard approach used by MAS-East. As MAS is a national programme the process could be spread and used by all the regional MAS. This would enable widespread and comprehensive testing of the process.

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APPENDICES

Appendix A – Structure of the planning day with the organisations

09:30 – 10.30 Review company background and objectives with the Managing Director (MD) or Senior Manager. Typical information reviewed was: the organisation chart, typical process routes for products, plant layout and a production plan.

The purpose of this part of the day was to gain an understanding of the business environment in which the company operates and any key business issues.

10:30 – 11.00 Walk the manufacturing route, with the MD / Senior Manager, from customer order entry to despatch and get introductions to the key personnel in the process.

11:00 – 12.30 Follow the route **independently** discussing and informally interviewing person(s) in each area who are close to the process.

12.30 – 13.00 Working lunch with some of the stake holders. The aim of this is for an informal discussion with the key personnel in a group situation.

13.00 – 14.30 Continue following route whilst digging into detail of the process and issues.

14:30 – 15.45 Reflect on and organise findings, in a quiet room.

16:00 – 17.00 Discuss findings, recommendations and opportunities for cellular one piece flow with the stakeholders.

17:00 Close.

The structure and timetable for the day acted as a guide only, as flexibility to different companies with different organisational structures and different complexity of processes was required.

Appendix B - Presentation to Companies on the First Day of Implementation

Shaun Danielli

Agenda

- Introductions
- JIT Game
- Lean Manufacturing
- 7 Wastes



Paired Introductions

Take 5-10 mins for this exercise

Interview the person next to you.
Establish the following information
about your partner...



1. Name (or name they will own up to)
2. Position within the company and length of service
3. Do they have any relevant experience in this particular area?
4. Something interesting about them; hobbies, interests, fetishes etc.
5. Do they have fears or concerns relating to this workshop?
6. Do they have any ideas or objectives for this workshop?

Some Workshop Guidelines...

- Be non blaming, non judgemental
- Ask questions any time
- There is only one meeting
- Everyone on the team is equal – nobody 'knows best' (Apart from me)
- Be up beat and put your views across
- It should be open, fun and enjoyable
- Having to listen to me talk all day wont be any of these. Keep it interactive



Psychometric Test / Thinking Styles



Reflects on Thinking. - Thoughtful & Caring



Thinks about the Team. - Solid and Reliable



Thinks outside the box. - Creative

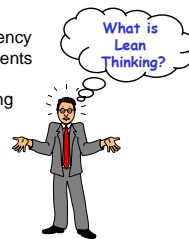


Just thinks about the Weekend !

Lean Thinking ????

Lean Manufacturing gives:

- Better Customer Service
- Improved Productivity & Efficiency Through Team Based Improvements
- Better Working/Less Frustrating Working Conditions



What Lean Is Not !!!

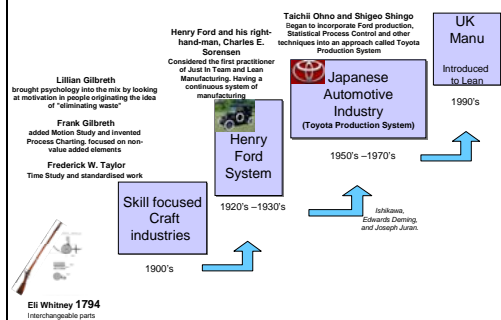


Lean Manufacturing

- Lean Manufacturing derives from the Toyota Production System or **Just In Time Production**
- **Henry Ford** and other predecessors. *The lineage of Lean manufacturing and Just In Time goes back to Eli Whitney and the concept of interchangeable parts.*



History of Lean Manufacturing

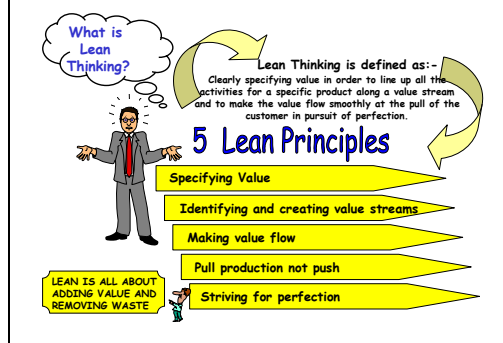


Why Do Lean Manufacturing

- Productivity gap with USA & rest of Europe.
 - Of up to 55%
- Competition
- Low Cost Economy (China / East Europe etc)

- Therefore:
 - Moving up the Value Chain
 - This and delivery are key competitive advantages
 - Need for Continuous Improvement

Lean Thinking



No.1 Define Value

Value can only be defined by the ultimate customer...



"Value is only meaningful when expressed in terms of a specific product or service which meets the customer needs at a specific price at a specific time"

No.2 Identify the Value Streams

The value stream is a set of actions required to convert a specific product through the *three* critical tasks of any business into the arms of the customer:-

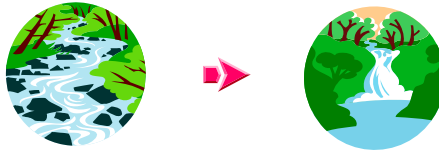
1. **Pre-production:-**
Concept, detailed design, engineering & first article.
2. **Information Management:-**
Running from order taking, through scheduling to delivery
3. **Physical Transformation:-**
From raw material to finished product into the customers hands



Identifying the *entire* value stream for each product as it moves through these stages is the next step in the journey to lean

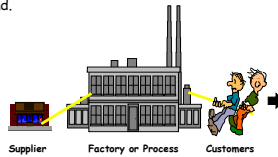
No.3 Make 'Value' Flow

Products should flow through a lean organisation, the rate at which the customer needs them, without being caught up in inventory or delayed. Make the value stream flow. As far as possible use one piece flow to keep products moving and thus avoid batch and queue



No.4 'Pull Not Push Value'

Only make as required.
Pull the value according to the Customer's demand.



No.5 Strive for Perfection

Perfection does not just mean quality. It means producing exactly what the customer wants, exactly when the customer requires it, at a fair price and with minimum waste



Perfection will never be achieved, as it is always possible to improve, therefore the process should start again at step No.1

Lean Thinking is...

The 'key' 5 Lean Principles

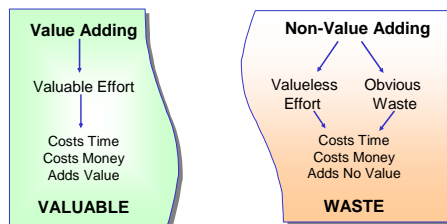


- Specifying Value
- Identifying and creating value streams
- Making value flow
- Pull production not push
- Striving for perfection

LEAN IS ALL ABOUT ADDING VALUE AND REMOVING WASTE

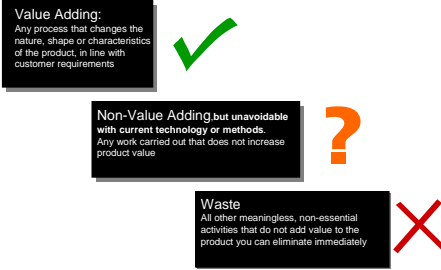
What is Waste ?

Two Elements to Every Job

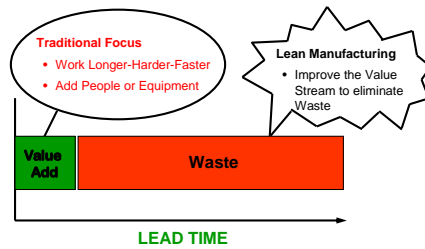


Where do we draw the line between Waste & Non-waste elements?

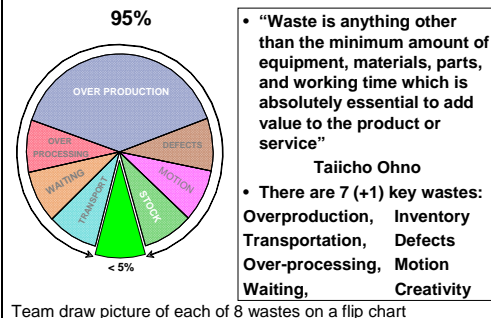
Types of Work - Identifying waste



Waste Elimination



Typically V/A is less than 5%

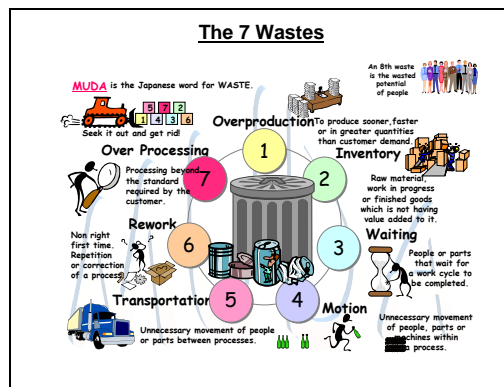


Team draw picture of each of 8 wastes on a flip chart

Rough Guide to Waste

“Only an activity that physically changes the shape or character of a product or assembly can add value”

“Any activity that does not change the product or assembly is waste”



Classify Activities As Waste / Non-Waste

All the activities below require effort, cost time and cost money, but not all physically change the shape or character of a product of assembly (and therefore cannot add value). Which ones are waste?

Waste (Y/N)		Waste (Y/N)
_____	Machining cut	_____
_____	Plating	_____
		Assembly

Use the "Rough Guide to Waste" to identify waste

Rough Guide to Waste - Conclusions

- **Effort frequently does not result in changing the shape or character of a product or assembly**
Eg. moving, counting, expediting, setups, inspecting, etc
- **Changing shape or character of a product or assembly does not necessarily add value**
Eg. machining, plating, assembly, painting, heat treating, etc
- **The more waste you can see, the more you can eliminate**
 - If you accept activities as waste, you may devise methods to eliminate them. YOU choose whether to tolerate the waste!

Overproduction

Avoid overproduction by balancing supply to demand



- **Overproduction is the worst kind of waste because it causes other wastes and obscures the need for improvement**
- **Overproduction waste results from producing more (or faster) than required**
- **Overproduction is caused by**
 - Large batch sizes
 - Unreliable processes
 - Unstable schedules
 - Unbalanced cells or departments
 - Working to forecast / inaccurate information not actual demand

Over-production



Why a Waste?:

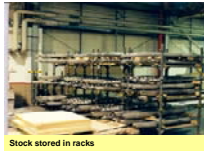
- Costs money
- Consumes resource ahead of plan
- Creates inventory
- Hides inventory/defect problems
- Space utilisation

Caused by:

- MRP push rather than kanban pull
- Large batch sizes
- Looks better to be busy!
- Poor people utilisation
- Lack of customer focus



Inventory



Stock stored in racks

Why a Waste?:

- Adds cost
- Extra storage space required
- Extra resource to manage
- Hides shortages & defects
- Can become damaged
- Shelf life expires

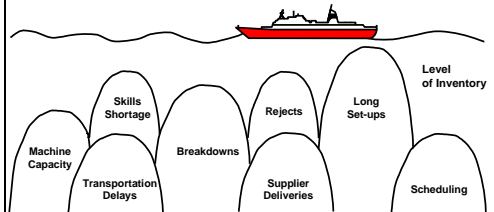
Caused by:

- Production schedule not level
- Inaccurate forecasting
- Excessive downtime/set up
- Push instead of pull
- Large batching
- Unreliable suppliers



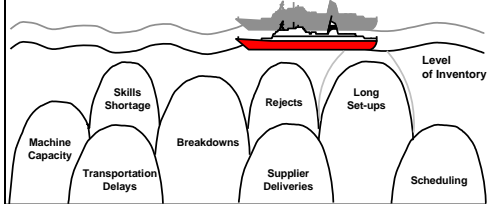
Thousands of parts in one of many stores

Reducing Overproduction & Inventory



Overproduction and Inventory hide causes of Waste
(otherwise, why would we hold them?)

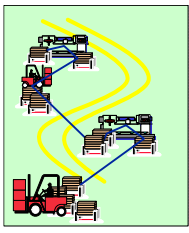
Reducing Overproduction & Inventory



Solve problems to reduce the level of inventory in the
manufacturing system... and reduce the level of inventory in the
system to prevent problems returning!


Transportation

Poor layout exacerbates transportation wastes



- **Transport waste is material movement that is not directly associated with a value adding process**
- **Processes should be as close together as possible and material flow directly from process to process without any significant delays in between**
- **Excess transportation may be caused by :**
 - Poor layouts
 - Large distance between operations
 - Lengthy, or complex material handling systems
 - Large batch sizes
 - Working to faster rate than customer demand (overproduction)
 - Multiple storage locations

Transportation



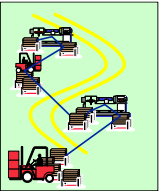
Returning jigs

Caused by:


- Badly designed process/cell
- Poor value stream flow
- Complex material flows
- Sharing of equipment

Why a Waste?:

- Increases production time
- It consumes resource & floorspace
- Poor communication
- Increases work in progress
- Potential damage to products



(Scrap, Rework and Defects)




Scrap Bin

Caused by:

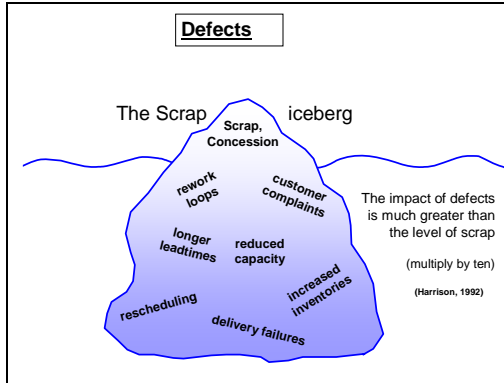
- Out of control/incapable processes
- Lack of skill, training & on the job support
- Inaccurate design & engineering
- Machine inaccuracy
- Black art processes

Why a Waste?:

- Adds costs
- It interrupts the scheduled
- It consumes resources
- It creates paper work
- Reduces customer confidence



Scrap Material



Over-Processing

Checking every component

Caused by:

- Out of date standards
- Attitude - 'Always done it like this'
- Not understanding the process
- Lack of innovation & improvement
- Lack of standard operation procedures

Why a Waste?:

- It consumes resource
- It increases production time
- It's work above and beyond specification
- Can reduce life of component

Painting aircraft structure (to be rubbed down)

Motion

Collecting materials from a central store

Caused by:

- No standard operating procedure
- Poor housekeeping
- Badly designed cell
- Inadequate training

Why a Waste?:

- It interrupts production flow
- Increases production time
- Can cause injury

Collecting tools for the job

Work smarter not harder

Waiting



Products waiting for shortages

Why a Waste?:

- Stop/start production
- Poor workflow continuity
- Causes bottlenecks
- Long lead times
- Failed delivery dates

Caused by:

- Shortages & unreliable supply chain
- Lack of multi-skilling/flexibility
- Downtime/Breakdown
- Ineffective production planning
- Quality, design, engineering Issues
- 'Black art' processes



Kits waiting to be processed

Under Utilisation Of People

- How could we better involve people in continuous improvement?



Under-utilised People

- How could we make better use of people's time?

Overview of Lean Manufacturing

The Benefits...

- **Improved**
 - Customer Service - On time in full
 - Productivity hence value add
 - Quality and problem solving
 - Staff innovation and morale
- **Reduced**
 - Waste, transport, moving, space etc
 - Lead time, response time and delay
 - Work in progress and capital
- **Flourish or Survival**

Suggested Reading



•Lean Thinking

Womack & Jones



•The Lean Toolbox

John Bicheno



•Who Moved My Cheese ?

Spencer Johnson

Appendix C – The Buckingham JIT Game Explanation

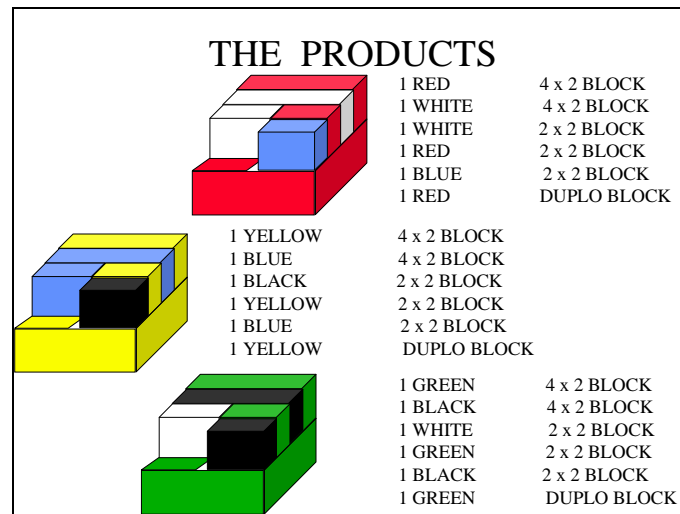
Note: This explanation of the Buckingham JIT game is based on the instructions and rules provided with the game and an internet search. It is not the original work of the author.

Background

The simulation or game is played over 4 to 5 rounds of 11 minutes each. A 5 round game normally takes two hours. The game is played with a team of up to 15 people. The objective of the game is to maximize the profits of the ‘company’.

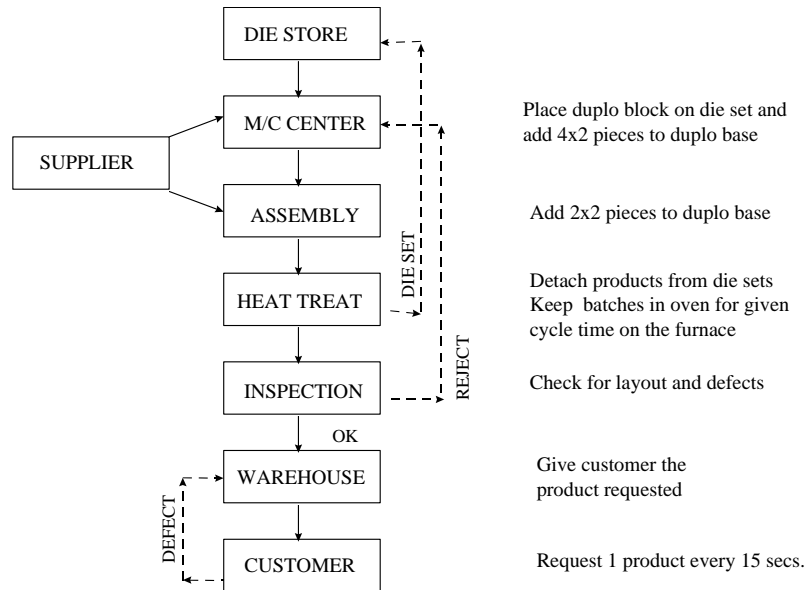
Materials

The game is played with Duplo and Lego blocks. The team has to assemble these blocks in a particular order that make up the product. There are three products, distinguished by the colour of the base Duplo block (Red, Green and Yellow) and the arrangement on top of the base block.



People and Processes

To begin, there is one "worker" sitting at each of the eight stations depicted in the process flow chart below. In addition, there are 2 or more material handlers. At the beginning of the first round, the instructor sets up the layout of the process flow. The layout is deliberately set up in a convoluted way so that sequential processes in the flow chart are located far from each other in the physical layout. – As if often the case in factories. This will force the players to think about rearranging the layout for subsequent rounds for better material flow.



The production flow follows the same route for all the products on a first-in-first-out basis. The game starts with an initial inventory of 5 Reds, 3 Green and 3 Yellow products in the warehouse. The production team makes these products during their practice session, before the game starts. At the beginning of the game, there is no work-in-progress inventory. The customer demand mix is approximately known to be 2:1:1 for Red, Green and Yellow. However, the sequence is random. The customer has a deck of index cards marked with a Red, Green or Yellow, indicating the product being requested from the warehouse.

The team starts out with Schedule 1 of the Master Production Schedule (MPS) where they will produce the products in batches (8 Red, 4 Green and 4 Yellow).

The MPS shows a Blue block. The Blue block is used for clocking the Lead-time. It is treated as a Red product. The lead-time is measured from the time this block starts at the machine centre till it reaches the warehouse.

The customer starts and stops the game. 30 seconds after having called the start of the game, the customer takes a card from the deck and requests the warehouse to supply the piece. The customer demands a product every 15 seconds. The cards are shuffled at the start of each round of the game.

When the customer calls out the start of the game, the machine centre and assembly orders the number of pieces that each of them require from the supplier. The material handlers are used for transporting pieces from the supplier to each of the centres. The machine centre also has to obtain the correct colour die set from the die store. Again, a material handler is used for this purpose.

Each die set is a 16 X 8 lego block. Each die set can accommodate at most 4 duplo blocks, i.e., 4 products. So when the machine centre is following schedule 1 of the MPS, the machine centre has to order two die sets of Red. The machine centre operator places the duplo block on the die set and 2 pieces of 4 X 2 lego block, based on the product colour.

Next, the complete die set along with the duplo blocks is sent to the assembly (via a material handler). At this time, the machine centre supervisor checks the MPS and orders the next die set from the Die Store (via one material handler) and the necessary 4 X 2 lego blocks from the Supplier (via another material handler). Meanwhile, the assembly centre has received the first batch. The Assembly supervisor orders the appropriate colour and quantity of 2 X 2 lego blocks (based on the die set and product colour) from the supplier (via a material handler). Once the materials arrive, the assembly worker adds the 3 pieces of 2 X 2 lego blocks to each product unit in the die set.

The assembly centre then sends the product batch, along with the die set, to the heat treat via a material handler. At the heat treat, the product is detached from the die set and placed in the furnaces by the heat treat worker. Both teams, in their first round, start out with the BIG furnace, which accommodates up to 8 products. The furnace is switched “on” only when it is full. The heat treat supervisor indicates start and stop time for the furnace. That supervisor uses a stopwatch to assure that the time that each batch spends in the furnace is the same as that given on the furnace sheet.

When the heat treat process is complete, the heat treat worker unloads the oven. The heat treat supervisor then sends the batch of products to the inspection station via a material handler. The inspector checks for external defects and for the correctness of the arrangement in which the lego blocks have been placed on the duplo blocks. Any defective products are noted on a count sheet and sent back to the machine centre via a material handler. The machine operator has to disassemble the product and perform re-work. Good products are sent to the warehouse via a material handler.

The game ends when the customer runs out of all the index cards. There are 40 index cards, so each round of the game takes 10 minutes. The customer should count how many products have been delivered on time (that is, immediately upon request), how many delivered late (that is, not when requested, but during the round of play), and how many defective. Defectives are to be returned to the warehouse via a material handler. These defectives are held in the warehouse as scrap until the end of the round.

The warehouse worker should also keep track of how many products are delivered upon request, how many delivered late, and how many returned because of defects. In addition, the warehouse worker should keep a count for backordered products (i.e., ordered by the customer, but never delivered during the round.) At the end of each round, the warehouse worker should hold onto the initial Finished Goods Inventory (FGI) for the next round. The initial FGI for each round is 5 Red, 3 Green and 3 Yellow products.

The Changes between Rounds

At the end of each round the instructor will collect the results data, enter it into the game spreadsheet, and determine each team's performance (plant gross margin). The teams have 15 minutes to discuss their performance and decide upon, at most, two process changes from those listed as possible changes in an effort to improve the team's performance in the next round.

There are nine possible changes. Eight of these are possible *process* changes. The ninth possible change is *personnel restructuring*. Some process changes may require personnel restructuring. Some personnel restructuring changes are entirely voluntary. For each round, a team may make as many personnel restructuring changes as they like or as are required by their process changes.

The teams cannot change the product design or the manufacturing sequence. The customer cannot communicate with anyone other than the warehouse worker and the initial finished goods inventory should be the same in each round. After each round the students should disassemble all products and return them to the supplier.

Revenues and Costs

Revenues:

Red product	£400 each
Green/Yellow products	£300 each
Late delivery	£50 each
Returns (defective)	£100 each charge and loss of revenue

Material costs:

Red Duplo Block	£60 each
Green Duplo Block	£30 each
Yellow Duplo Block	£30 each
Red 4 X 2 Lego block	£25 each
All other 4 X 2 Lego Blocks	£20 each
All 2 X 2 Lego Blocks	£10 each
Standard material cost of red product:	£135
Standard material cost of green/yellow product:	£100
Labour costs (Direct and Indirect):	£50 per period

Overhead costs (players do not see this):

Basic Overhead

Building and equipment	£500 per period
Inspection equipment	£100 per period
Scheduling system – internal	£200 per period
Scheduling system – external	£200 per period
Defects	£100 per defect plus lost time/sale
Power	£0.50 per unit started

Possible Changes Between Rounds (and Associated Costs)

Personnel changes (not part of the 2 change limit)

- Retrain an individual to work on a different task (and pay rate), \$100 per person trained
- Lay-off an individual
- Hire and train an individual

Process Changes:

- Relocate Die Storage to Machine Centre
(frees two workers, die store worker and material handler between die store and machining).
- Add or eliminate work position at 2 stations
(Balance amount of work done at each centre)
- Change Master Production Schedule (reduce batch sizes)
 - move from schedule 1 to schedule 2
 - move from schedule 2 to schedule 3
 - move from schedule 1 to schedule 3
- Change plant layout
- Initiate self-inspection
- Install new furnaces (replace current furnace with smaller one)
 - move from BIG to MED
 - move from MED to SMALL
 - move from BIG to SMALL
- Use internal Kanban system
- Use external Kanban system

Appendix D – Digital Photo from First Day of Implementation at Autoglym Ltd.



Microsoft Excel - JIT Game Scores Autoglym

JIT Game	Autoglym										
Round	Specials	On Time	Late	Not Met	WP	FGI	Rejects	Players	Productn	Profit	Per Year
baseline			crosses	dashes					Started	11 mins	PA
1	0	11	15	14	40	5	7	10	71	-124	1,302,000
re-balance line, mid heat treat, layout, move inspection											
2	0	21	9	10	31	0	1	10	55	-49	514,500
3	3	38	2	0	19	13	0	10	65	13	136,500
mini haet treat ,											
4	4	38	2	0	11	22	0	8	66	19	189,000
5	4	38	2	0	14	4	0	6	51	72	756,000

Preview: Page 1 of 1

Appendix E – Mock Up of Storage Units at Autoglym

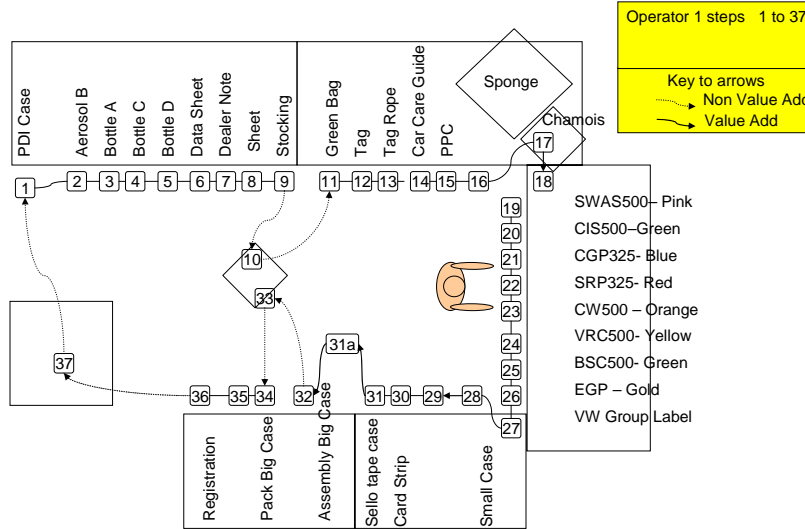


Appendix F – Digital Photo from Last Day of Implementation at Autoglym Ltd.

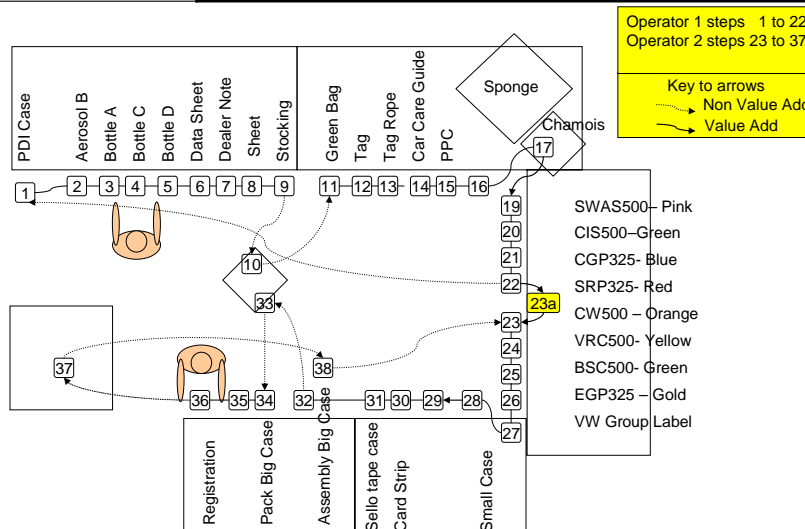


Appendix G – Autoglym Standard Operating Procedure

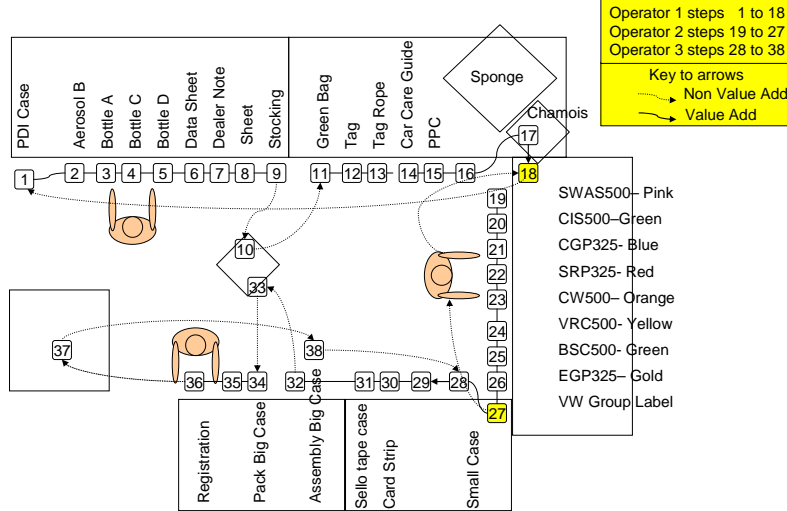
Standard Operations Routine Sheet No.1	Product	Required Daily Quantity	420 minutes/ required quantity (cycle time)	People in Cell
	<i>Life Shine</i>	<i>180</i>	<i>2 minute 20 seconds</i>	<i>1</i>



Standard Operations Routine Sheet No.1	Product	Required Daily Quantity	420 minutes/ required quantity (cycle time)	People in Cell
	<i>Life Shine</i>	<i>360</i>	<i>1 minute 10 seconds</i>	<i>2</i>



Standard Operations Routine Sheet No.1	Product	Required Daily Quantity	420 minutes/ required quantity (cycle time)	People in Cell
	<i>Life Shine</i>	<i>540</i>	<i>0 minute 47 seconds</i>	<i>3</i>



Cell Takt Time and Staffing Calculator

Product =	Life shine
Working Minutes / Day =	420
Minutes effort for 1 product =	2.33

Required Quantity	Takt time			People In Cell
	Minutes	Minutes	Seconds	
30	14.0	<u>14</u>	<u>0</u>	0.2
60	7.0	<u>7</u>	<u>0</u>	0.3
90	4.7	<u>4</u>	<u>40</u>	0.5
120	3.5	<u>3</u>	<u>30</u>	0.7
150	2.8	<u>2</u>	<u>48</u>	0.8
180	2.3	<u>2</u>	<u>20</u>	1.0
210	2.0	<u>2</u>	<u>0</u>	1.2
240	1.8	<u>1</u>	<u>45</u>	1.3
270	1.6	<u>1</u>	<u>33</u>	1.5
300	1.4	<u>1</u>	<u>24</u>	1.7
330	1.3	<u>1</u>	<u>16</u>	1.8
360	1.2	<u>1</u>	<u>10</u>	2.0
390	1.1	<u>1</u>	<u>5</u>	2.2
420	1.0	<u>1</u>	<u>0</u>	2.3
450	0.9	<u>0</u>	<u>56</u>	2.5
480	0.9	<u>0</u>	<u>53</u>	2.7
510	0.8	<u>0</u>	<u>49</u>	2.8
540	0.8	<u>0</u>	<u>47</u>	3.0

Appendix H – Implementation Checklist

Implementation Checklist for Company _____

A week before the implementation checked the following have been arranged.

Dates and Times

- The dates are... _____
- Their preferred start time is... _____
- The usual morning break time he is... _____
- The usual lunchtime is... _____
- The usual afternoon break time in is... _____
- Their preferred finish time is... _____

Champion

- The name of the champion is _____
- Who is doing the “Need for change” introduction? _____

Team Members are

There Role Is

- 1. _____
- 2. _____
- 3. _____
- 4. _____
- 5. _____
- 6. _____
- 7. _____
- 8. _____
- 9. _____
- 10. _____

- Who will be the kernel of the next team after massive left? _____

Detail

- Have Seven movable tables have been arranged for the JIT Game? _____
- Has a flip chart on lakes has been arranged? _____
- Has a sheet of address labels for name badges has been arranged? _____
- Has demanded data for the product group being gathered? _____
- Have you built-up 2 days stock? _____ Or will the line run ? _____
- Have you videoed the products that we would miss? _____
- Have you arranged a data projector? _____
- There any customer visits we should be aware of? _____
- Are there any other important things that we should be aware of? _____
Are there any important things that you would like to know?

Appendix I – Example of Action List from end of Day 2 of Delta Designs Implementation

DELTA.

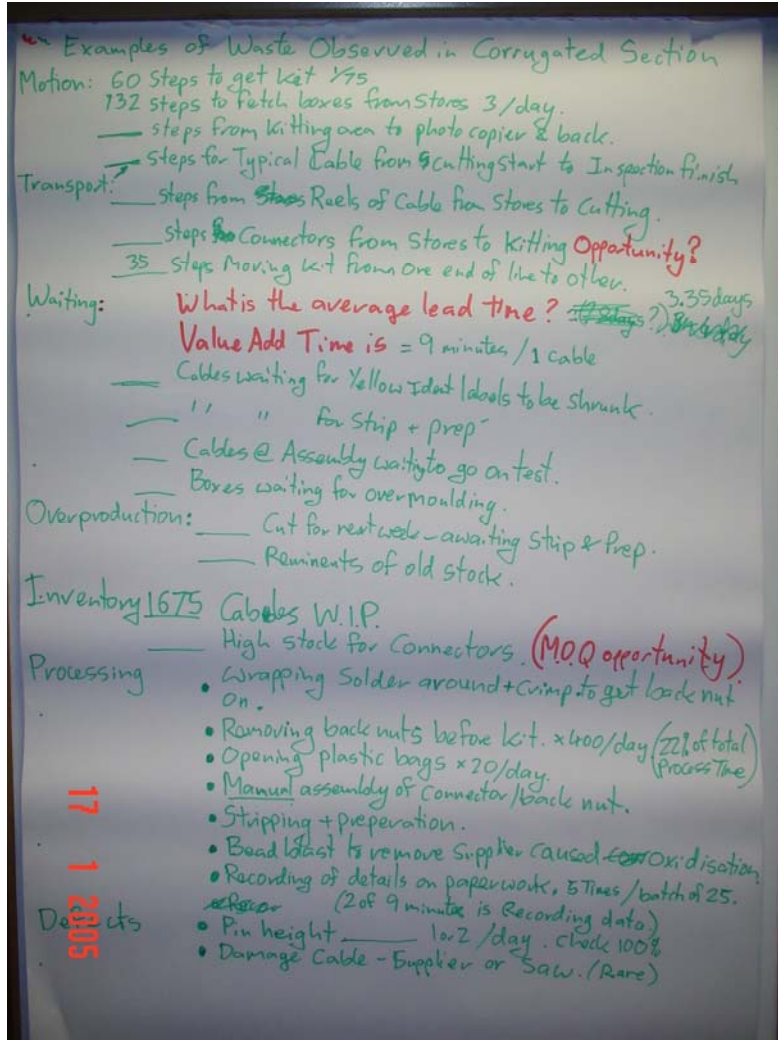
ACTION	WHO	WHEN	BLOCKER REMOVAL
1) CROSS TRAIN OF ASSY TEAM	MARY	4/2	
2) 'SHOPPING LIST' OF EQUIP TO DO 2ND STATION	BRUCE	4/2	
3) BEACON HOLDER JIG FOR STICKING LABEL ON	"	25/2	
4) BASE + LOOSE BOX HOLDER	"	25/2	
5) SMALL TABLE FOR LOADING BOPF OUTER CARTONS	"	25/2	
6) REVIEW OF HOW THE SDO RUN WENT. IMPROVEMENTS etc	STEVE	4/2	
7) INVESTIGATE REPLACING O RINGS + LUB. WITH SILICONE (OR SOMETHING).	STEVE	25/4	
7b) INVESTIGATE HOW TO LIVE WITH 'O RINGS' + LUB + STILL RUN DOWN LINE.	STEVE	4/2	
8) KITS READY TO RUN IN 'TEST AREA' FOR 4/2	OLGA	3/2	
9) LABEL DISPENSING	BRUCE/		
10) RACKING	BRUCE/		

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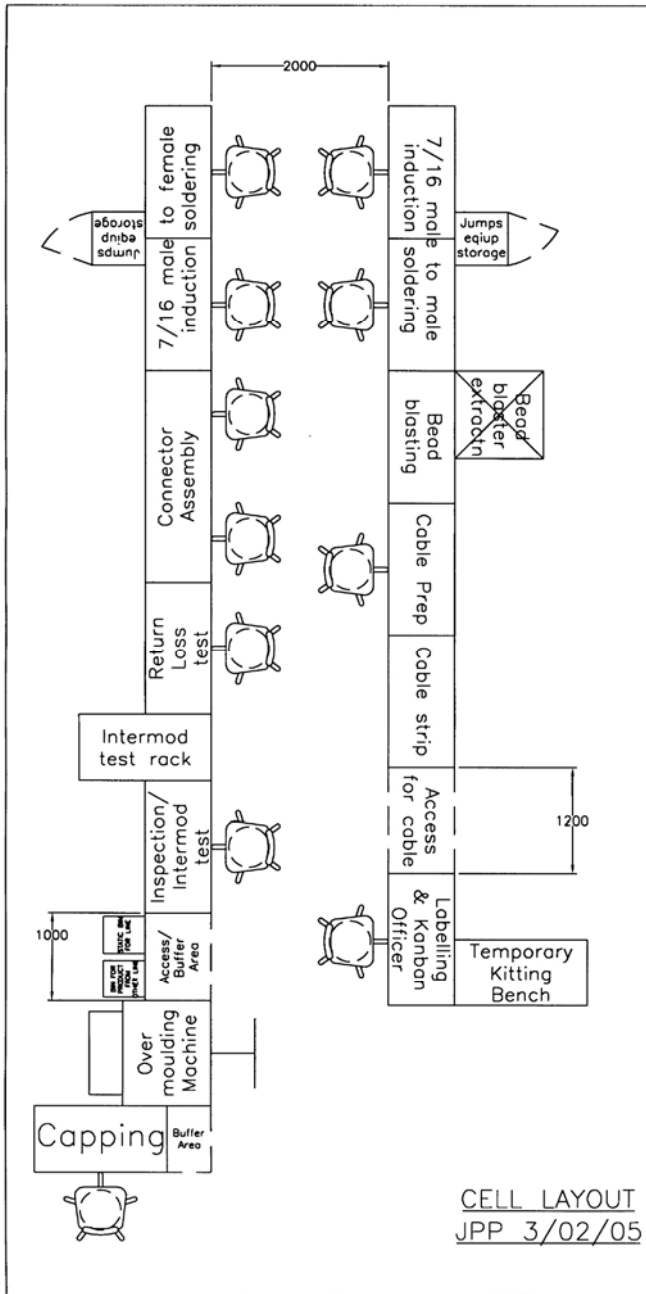
Appendix J – Example of Some of the Jigs Made Up During the Delta Designs Implementation

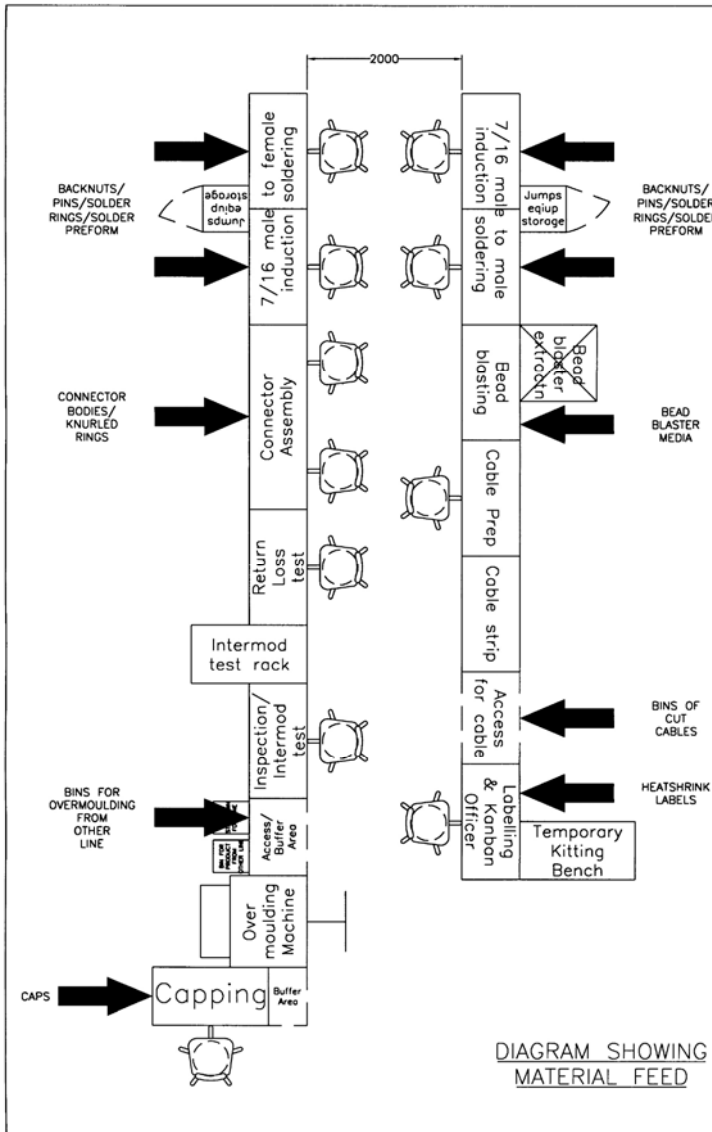


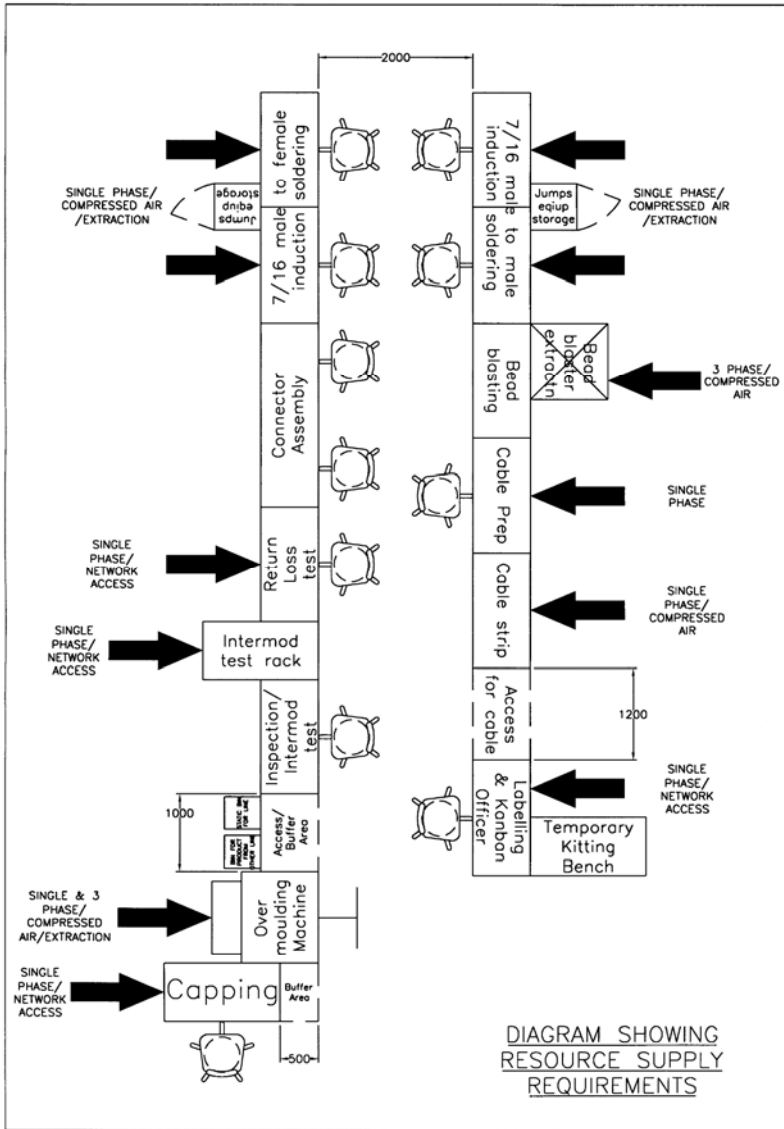
Appendix K – 'Waste Watch' on 2nd Day of Quadrant Implementation



Appendix L – New Layout of Quadrant







Appendix M - Photo of the One Piece Flow Cell at Quadrant Connections in Action



END