The Adoption of Lean Sigma in a UK Longitudinal Manufacturing Case Study

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Abstract

The power and influence of the individual techniques of Lean Production (L.P.) and Six Sigma (S.S.) are well recognised as successful manufacturing Continuous Improvement (C.I.) and Change Management (C.M.) methodologies. Both techniques are able to be successfully introduced and applied in the manufacturing companies of the UK with both techniques having a history of successful performance improvement. The hypothesis the research attempts to test is founded upon the limitations of the independent adoption of the techniques in contrast to the development of a more powerful Lean Sigma synergy, blending both techniques in a combined approach. The tools used individually limit the potential and pace of the manufacturing business development with both improvement systems having hard limits and constraining boundaries that the fundamentalist supporters are unable or unwilling to question.

This research aims to prove that the cocktail of the techniques known as Lean Sigma (L.S.) can significantly improve the ability of the manufacturing business to accelerate the C.I. process whilst maintaining a more structured and disciplined roll out process that combines the creative waste reduction of L.P. and the statistical improvement and management techniques of S.S. Breaking down the constraints and hard limits of the individual techniques by harnessing the most powerful and

influential elements of the two systems to produce a significantly more holistic C.I. programme that delivers the penetration and flexibility of Lean combined with the structure and rigour of Six Sigma. This research follows the migration from the C.I. methodology of Total Quality Management (T.Q.M.) to the acceptance of Lean Sigma in a UK manufacturing case study and is supported by three satellite UK longitudinal manufacturing case studies.

The resultant case study analysis attempts to uncover evidence to defend the criticism that the two techniques are mutually exclusive and furthermore that they have a significant combined and complementary impact on the case study businesses that have accepted the dual attack strategy of Lean Sigma. By the process of becoming partial embedded in each of the case studies the researcher has experienced the longitudinal change process first hand and plotted the nuances in each of the studies, comparing and contrasting the differing approaches to the adoption of the methodologies and the roll out strategies. The findings of the research highlight the increased impact of the combined approach in areas as diverse as workforce commitment, floor space utilisation, machine up time, reduced labour requirements reduced tooling costs, component quality improvements, health and safety advances, process efficiency and cost reduction activity.

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Glossary of Terms and Abbreviations

The field of Continuous Improvement includes a number of technical words and phrases that may at first glance appear to emanate from an alien language, to ensure the reader is comfortable with the terminology used throughout this thesis the following list highlights the definition of the most significant problematic abbreviations, technical terminology or Continuous Improvement phrases:

Term or Abbreviation	Definition of the Term or Abbreviation
Agile Production	A school of thought dedicated to meeting customer needs through a holistic, flexible approach to manufacturing, rejecting the process of chasing waste reduction without consideration of the customers needs
ANOVA	The Six Sigma technique aimed at measuring or comparing the 'Analysis of Variance' or variation in statistical experimentation results
Autonomation	A state of highly tuned and well trained Lean Production operators performing as consistently as machines in a balanced and smoothed production line environment
B.T.O.	Build to Order manufacture processes that focus upon commencing the production process as and when a customer orders and quickly delivering a customer bespoke item
Benchmarking	The active process of comparing facilities and manufacturing processes to define best practices
Black Belt	Full time project based Six Sigma position
C.I.	The drive towards the use of Continuous Improvement activity to constantly attack waste and inefficiency in any process of a facility or business
Chaku-Chaku	The Lean Production manufacturing term for operators simultaneously loading and unloading a tool or machine in line with the pace of the production line to deliver maximum operator efficiency
Champion	Six Sigma program sponsor
C. of F.	Cost of Failure assessment aimed to expose waste and potential improvements or financial opportunities in an initial assessment process often used to commence the Six Sigma roll out in a business or facility
DOE	Design of Experiment, the statistical approach used in the Six Sigma improvement process

FMEA	Failure Mode and Effect Analysis the corrective action plotting process that attempts to identify the effect, impact and resolution to product failure
Gemba Kaizen	Lean production based workshop management and improvement processes
G.R. & R.	Gauge Repeatability and Reproduction, analysis of measurement system performance in terms of error contribution resulting from the measurement process and used to qualify the metrics prior to improvement activity commencing
Green Belt	Part time Six Sigma position
J.I.T.	Just in Time, logistics activity to deliver to the assembly facility as needed or time phased throughout the working day
Jidoka	Autonomation activity with the inclusion of the ability to stop the line at any given time
Heijunka	Production levelling or schedule smoothing techniques used to remove peaks in demand
Kaizen	The Japanese Process of evolutionary incremental improvement moving the business forward inch by inch
Kaizen Blitz (Time Constrained)	The westernised aggressive use of the tools of Lean Production in a time constrained activity that is normally over five working days and focused on a 'Just Do It' mentality to drive in change to the work place
Kanban	The 'Signal' used in Lean Production to ensure material flows to the assembly areas as and when required in the quantities required
Late Point Identification	Commencing with 'Modular' product design that aims to manufacture a base item and then focusing upon finish it off to the customers own specification at the end of the assembly line or in the storage areas of a facility
L.M. or L.P.	Lean Manufacturing or Lean Production
Lean Manufacturing	The time based assembly techniques generally accepted to emanate from the Toyota Automotive company
L.S.	Lean Sigma
Lean Sigma	The synthesis approach of Lean Manufacturing and Six Sigma taking the best of both techniques with the flexibility and penetration of Lean Manufacturing and the rigour and project management of the Six Sigma school
Master Black Belt	Full time Six Sigma Leader
Muda	The Japanese term used to capture exposed waste in the manufacturing system with much of the Lean process aimed at driving out Muda from the system
Poke Yoke	The 'Error proofing' tool favoured in Lean Production

	manufacturing facilities to ensure that a fault can not be built into a product
Q.F.D.	Quality Function Deployment a product and system design process attempting to convert customer wants through to manufacturing process and eventually through to products
SMED	Single Minute Exchange of Dies or rapid tool change over activities developed at Toyota to ensure maximum machine 'Up Time'
S.S.	Six Sigma
Six Sigma	The Motorola founded statistical improvement process that aims to move a businesses process to the state of near perfection of 3.4 parts per million failure whilst addressing the significant Cost of Failure exposed across the entire business
Single Piece Flow	Manufacturing components or products one piece at a time with minimal work in progress on the production line
S.P.C.	Statistical Process Control methodology to monitor process deviation from inputs or outputs of key measures and subsequently developing an action plan to ensure ongoing capability
Takt Time	The 'beat' of the customer's true requirements and the process to manufacture only to the customers wants and not for stocking purposes
T.B.M.	Time Based Manufacturing in line with the Toyota manufacturing system of Continuous Improvement and waste reduction
T.M.S.	Toyota Manufacturing System
T.P.M.	Total Productive Maintenance of machinery or tooling to ensure maximum machine 'Up Time' in the manufacturing process and guaranteed smooth production flow
T.P.S.	Toyota Production System
T.Q.M.	Total Quality Management
U Shape Cell	Manufacturing production line design used to perform single piece flow manufacturing and to improve operator efficiency whilst removing work in progress from the system
Weibull Analysis	The statistical analysis technique used to evaluate the performance of products using a small sample tested to destruction to subsequently predict the performance of the entire population of products
W.I.P.	Work In Progress
5 S.	The Lean Production workshop management and area improvement tool used to drive discipline and control as a precursor to the establishment of true Lean Production

Table of Contents

Abstract		**I**
Acknowledgements		**III**
Glossary of Terms and Abbreviations		**IV**
Table of Contents		**VII**
Figures		**XI**
Tables		**XII**
		Page
Chapter 1.	**Aims and Objectives of the Thesis**	**1**
1.1	The Rationale of the Research Activity	**2**
1.2	The Overall Approach	**4**
1.3	The Contribution to Knowledge	**5**
1.4	Background to the Research	**6**
1.5	The Research Phases	**9**
1.6	Overview of the Thesis Structure	**15**
Chapter 2.	**Continuous Improvement: Origins and Evolution**	**17**
2.1	Commencing with Craft Production	**20**
2.2	The Birth of Mass Production	**22**
2.3	Learning to be Lean	**24**
2.4	Agility	**28**
2.6	Lean Systems and Tools	**36**
2.7	The Development of the Six Sigma Movement	**41**
2.8	Six Sigma – The Management Program	**44**
2.9	From Motorola to America's Tool of Choice	**48**
2.10	The Synthesis of Lean and Six Sigma	**52**

2.11	E-Manufacturing To Order (E-MTO)	**61**
2.12	Business Migration and the Management of Change	**67**
2.13	The Summary of the Literature Review	**72**
Chapter 3.	**The Research Methodology**	**74**
3.1	The Research Question	**76**
3.2	The Selection of Case Studies	**80**
3.3	The Development of a Research Protocol	**81**
3.4	The Field Research Conducted	**82**
3.5	Data Collection, Documentation and Comparison	**84**
3.6	The relationship of the research program and current work	**85**
3.7	Project maturity – Migration from the original objective	**86**
3.8	The Case Study process	**89**
3.9	Assessment and Development Matrix	**92**
3.10	The use of Case Studies in Operations management	**93**
3.11	Case Study Process and the use of the Yin Methodology	**95**
3.12	Case Study Selection Process	**97**
Chapter 4.	**Case Study Analysis – Case Study A.**	**99**
4.1	Company Background	**99**
4.2	The Manufacturing Development Process	**103**
4.3	Lean Production & Breakthrough Kaizen	**105**
4.4	The Six Sigma Corporation	**106**
4.5	The Development of the Lean Sigma (LS) Tool Box	**110**
4.6	The Supply Chain Productivity Process	**119**
4.7	Lessons Learnt From the Introduction of SS	**128**
4.8	The Next Steps for the Lean Sigma Process	**132**

4.9	Migration Path	**142**
4.10	**Satellite Case Study - B**	**145**
4.1	Company Background	**147**
4.12	The Road Onwards from TQM to Lean	**162**
4.13	Phase 1 - The Breakthrough Kaizen Kick Start Program	**166**
4.14	Phase 2 - The Launch of Six Sigma	**169**
4.15	Migration Path	**175**
4.16	**Satellite Case Study - C.**	**178**
4.17	The Global Company	**180**
4.18	The Strategic Master Plan	**182**
4.19	The Global Supplier Initiative	**184**
4.20	The Site	**185**
4.21	The Structure of the Lean Sigma Team	**189**
4.22	Project Identification and Selection	**192**
4.23	The Black Belt and Master Black Belt Certification Process	**194**
4.24	Knowledge Management	**196**
4.25	Migration Path	**199**
4.26	**Satellite Case Study - D.**	**200**
4.27	The Rollout Strategy	**207**
4.28	The Business	**210**
4.29	The Partnership Approach	**214**
4.30	The Goal and Migration Path	**216**
4.31	The Cross Case Analysis	**220**

Chapter 5.	**Synthesis and Findings of the Study**	**242**
5.1	Literature Review Process	**243**
5.2	Commencing with Lean	**246**
5.3	Development of Six Sigma	**250**
5.4	Top-Down commitment and cultural acceptance	**253**
5.5	Lean Sigma	**258**
5.6	Acceptance and Buy-In	**264**
Chapter 6.	**Conclusions, Limitations and Next Steps**	**273**
6.1	Concluding Remarks	**274**
6.2	Completion of the aims and objectives of the study	**278**
6.3	Theory and Methodology of the Case Study Process	**282**
6.4	Limitations of the Research	**294**
6.5	Recommendations for Further Research	**297**
6.6	Reflections on the Research Process	**301**
References		**302**
Appendices		

Figures

1.6.1 Flow Chart Overview of the Thesis Structure	**Page**	**16**
2.10.1 The Development of Lean Sigma		**53**
2.10.2 The Lean Sigma Cycle		**55**
2.10.4 Lean Sigma Performance Chart		**59**
2.11.2 The Lean Sigma Development Pyramid		**66**
2.12.1 The Kotter Change Model in a Lean Sigma Business		**70**
2.12.2 The Initiative Introduction Process		**71**
4.5.1 Case Study A – Key Historical Developments		**104**
4.5.2 The Supplier Development Schedule in Year 1. - Case Study A		**118**
4.11.1 Steps to World Class Manufacture - Case Study B		**154**
4.31.5 L. S. Tools in the Case Study Facilities at the Commencement of Study		**241**
4.31.6 L.S. Tools in the Case Study Facilities at the Conclusion of Study		**242**
5.5.1 The L.S. Cycle with SMED / DOE Highlighted		**261**
5.5.2 The Lean Sigma Development Sequence		**262**

Tables

2.4.1 The Comparison of the Lean and Agile Custom factory - Page 30

2.6.1 Summary Table of Lean Tools and Processes 40

2.7.1 MAIC Summary Table 42

2.7.2 Comparison of Six Sigma and TQM 43

2.9.1 Table of Six Sigma Tools and Processes 51

2.10.3 Table of the Synergies of Six Sigma and Lean Production 58

2.11.1 The Combination of Six Sigma, Lean Enterprise and E-Manufacturing 65

4.5.1 MAIC at Case Study A 114

4.3.3 Comparison of Case Study Company Profile 221

4.3.4 Comparison of the Manufacturing Evolution 222

4.3.5 Comparison of the Migration Paths Followed 223

4.3.6 Comparison of Historical Development Templates 224

5.6.1 Critical Success factors in the Strategic Launch of L.S. 271

Chapter 1 - Aims and Objectives of the Thesis

The day will not soon come when the problems of either the world or our own polity are solved. Since we do not know the shape of the problems we do not know the requirements for solution.

J. K. Galbraith 1958

The problems facing western manufacturing at the dawn of the new century are many and varied. Much industrial progress has been made since the days of Galbraith, with significant improvements in the quality, output and efficiency of western manufacturing. Inevitably, however, as groundbreaking solutions have progressed, problems have continued to hold pace, with new issues emerging to ensure that no vacuum has developed. The world of manufacturing, like the world of nature, abhors a vacuum. Significant increases in the intensity of global competition have posed fresh problems and issues for the manufacturing communities of the western world.

Manufacturing in the west finds itself travelling a parallel development path with the world of medicine, in which ever more radical treatments and cures are running hard to keep up with the development of ever more resistant super-bugs and diseases. Britain's post-war commonwealth and global markets are long gone. Starved of product, a cutthroat, competitive "dog eat dog" market place has replaced them with global competitors who are continually searching for new markets to dominate. James Dyson (2004) comments, "with China breathing down our necks, the only way we will be able to sell our products is if they have better technology and are better designed." The pace and intensity of competition both internally and externally require a complete reappraisal of both problem and solution by western manufacturing. An ever accelerating process of C.I. evolution is underway in many large western manufacturing organisations; they must evolve or be swept aside by the invading array of new goods produced in low-cost labour markets. With the growth of

single-use power tools and one-season clothing embodying the new reality faced by much of today's industry in the UK, industries that developed products centred on robustness and durability are being replaced by low-cost disposable offerings, shipped in bulk from the booming Far East economies.

This research aims to follow the longitudinal development path of a case study manufacturing facility in the UK progressing from the C.I. roots in the Total Quality Management (TQM) movement through the development of the techniques of Lean Production (L.P.) in it's manufacturing facility and onwards to the synthesis of the Lean tools with the statistical management technique of Six Sigma (S.S.) to form a working Lean Sigma (L.S.) improvement methodology, the core research activity being supported by the observation of three smaller satellite studies, each following similar development paths and facing comparable problems.

1.1 – The Rationale of the Research Activity

The drive to complete a longitudinal research activity is grounded in the author's quest to study at the cutting edge of operations management activity following the emerging themes in the field of manufacturing Continuous Improvement (C.I.) implementation. The research strategy can be considered as following an action research perspective in the core case study. With the use of the longitudinal case study methodology allowing the author 'hands on' change management experience in a significant UK manufacturing facility. In parallel to the core case study three satellite studies have allowed the author the opportunity to observe from a positivist stand

point the manufacturing facilities of three other UK companies operating in differing manufacturing sectors.

The case study methodology has proved an excellent vehicle to study emerging phenomena and the core case study activity plots the development path of the manufacturing facility from the Total Quality Management foundations of C.I. through the incremental path towards the eventual adoption and roll out of Lean Sigma. The action based research activity in the core case study highlighting the evolutionary development in the core case study and also recording the strategic thought processes. The core case study activity can be considered as founded on primary data, gleaned daily from the participation in the change management team of the core case study. In many ways the research is founded upon the study of inputs, actions, reactions and eventual outcomes and deals at the levels of individuals to highlight the complexity of the eventual end result of the longitudinal research. The research activity throughout the longitudinal study process has focused upon the development path taken by the case study facilities and the critical success factors and definitive mistakes identified along the way. The research process has focused upon the cultural C.I. starting point in each case study and progressed forward to review the migrations path taken by the individual case studies and the anticipated next steps identified by the change management teams present at the conclusion of the study.

The initial quest to record a migration path from the base foundations of Total Quality Management to Lean Manufacturing proved to be a single step upon a more significant manufacturing technology journey taking in the schools of Agile Production, Six Sigma and eventually Lean Sigma. The pace of change accelerated as

the competitive threat intensified for many of the case study facilities, changing the fundamental rules of engagement and introducing new competitors to over crowded market places.

1.2 – The Overall Approach

The overall research approach commenced with the construction of an initial situation analysis of C.I. sophistication in the core case study facility and a series of satellite case studies, reviewing the historical C.I. development within the facilities with an initial extended site based benchmarking activity. The activity continued throughout the research period with regular site visits to the satellite facilities and the use of a structured interview process to update a rigid interview matrix, combined with continued action research inside the core case study. In parallel to the onsite surveillance an extensive literature review was conducted to develop a holistic view of academic knowledge of the various schools of C. I. management and to continually monitor the emerging fields such as Six Sigma and Lean Sigma. The initial literature review established a significant knowledge base of C.I. methodology and a continued vigilance of the subject area has been maintained throughout the research to help keep the author up to date with the growth of material upon areas such as modular design for 'Build to Order' manufacture and the continued growth of Lean Sigma.

The research focuses upon the C.I. culture and sophistication levels of a core case study and three satellite studies throughout a longitudinal research process, focused upon assessing the strategic improvement direction, development path and improvement processes followed by each case study. The individual studies record

the path taken from T.Q.M. towards Lean Sigma and highlight the significant steps along the way whilst noting the critical success factors and limitations. The core case study allowing a detailed insight to the overarching, strategic direction of C.I. in a large UK manufacturing facility with an overview of the initiative roll out processes and tactical considerations of the emerging initiative of Lean Sigma. The satellite studies are compared and contrasted as they travel the C.I. road, providing excellent cross case analysis and a comparative model to contrast against the core case study. The research concludes with a review of individual migration paths and a comparison of shared themes, highlighted issues, and success factors and is drawn to a close by the identification of areas for additional study and future research opportunities.

1.3 The Contribution to Knowledge

The nature of longitudinal research activity in operations management aims to capture events as they unfold over an extended duration, documenting and recording the details as they unfold. The format followed through the duration of the case study activity has allowed the researcher to focus on both the questions of how and why over a period of time that proved sufficient to witness C.I. events emerge and mature. The research traced the development of C.I. methodology in a core case study and a series of satellite studies over an extended period, following the development of the facilities from advocates of T.Q.M. to the development of Lean Manufacturing, Six Sigma and Lean Sigma. The research can be considered as contributing to knowledge by exposing the migration paths of the individual case studies, linking the strategic rationale of the change management team as they react to the competitive stimuli of the day, to the individual facilities operational activities in skills and tool

development. The duration of the research allowing us to witness the cycles of activity, with leading blue chip facilities:

1. Identifying internal strategic weaknesses in the core and satellite studies.
2. Highlighting the growing external and internal competitive threats.
3. Recording the development and implementation of C.I. response strategies.
4. Focusing upon the critical success factors and considered failings.

The findings of the research have been synthesised into a series of implementation guidance notes and critical success factors, gleaned from both the action research in the core case study and the structured interviews, observation and analysis undertaken in the satellite studies. The thesis is concluded by the identification of potential subject areas for additional research for future students in the field of C.I. and operations management.

1.4 Background to the Research

Alvin Toffler's 'Future Shock' (1970) predicted the pace of change continuing to accelerate. In the manufacturing companies of the western world this has proved to be the case, Toffler later reflected (1998) that he probably understated the pace, breadth and diversity of the change that would sweep across the western world.

This research thesis aims to focus upon the logical development and deployment of the C.I. technique of Lean Sigma, a blend of the Japanese time based assembly technique known generically as Lean Manufacturing and the emerging American statistics based improvement techniques captured under the banner of Six Sigma. The author has studied the migration path taken by a UK case study organisation towards

the acceptance of Lean Sigma as the C.I. technique of choice, and includes active participation in the improvement process and manufacturing development of the case study company. The study is supported by a series of satellite studies of three other manufacturing case study organisations travelling similar paths. The case studies are bonded together by the common need to change or fade into oblivion. The research follows the dual study methodology of Leonard-Barton (1990), with the core longitudinal study being replicated in the smaller satellite studies.

The action based research process employed throughout the long migration path of the core case study has combined both theory and practice. In the process of researching this subject area, the author has put into practice pure and applied research techniques at various stages in the project, with a varied balance and division of action research and pure academic research in line with the tasks of the moment. The author has employed many of the established techniques of "Continuous Improvement" over the last ten years, and through the course of the case study research, the author has actively been involved in the development process of the key case study, contrary to the more normally accepted conventions of pure research being supplemented by a degree of application.

Commencing with a background in Total Quality Management and progressing through introductory activities in both the fields of Lean Production, along the transformation lines of Amano (1996), and also Harry and Schroeder's (2000) Six Sigma development process. The mutual compatibility of the tool sets was soon noticed, and a process of integrating the techniques commenced in the key case study manufacturing site. The pure research followed on from the initial practical

development activity within the core case study, with increasing research activity to support the concept of a migration path and development process moving the facility from Total Quality Management (TQM) to Lean Sigma (LS) as a number of individuals and other organisations commenced the development and study process that eventually led to the acceptance and application of the technique we now know as Lean Sigma.

The core research reviews the development of a case study organisation's migration from a mid-1990sTQM business to a LS operation, plotting the changes to its long-accepted manufacturing model, as employed in a significant manufacturing site in the north east of England. The research activity has been cross-referenced through the course of the research process by four additional supporting satellite manufacturing studies, with each of the study organisations travelling similar development paths and facing similar competitive, internal and external threats.

The case study companies have been selected from a number of differing industries, ranging from pharmaceuticals to power tools. A qualitative approach has been taken in the analysis of each case, with the study focusing upon:

- The historical foundations and recent C.I. developments.
- The present development period and the migration steps taken to-date.
- The future management vision for the case study facility.

The span of up to seven years from beginning to end of the case study activity has resulted in the documentation of significant change in each organisation, with similar dramatic changes also evident in the industry sectors of this research activity.

1.5 The Research Phases

At the commencement of the study period, the case study organisations could be considered to reflect a spectrum of differing levels of manufacturing sophistication and maturity. Through the course of the case study process, the author aims to highlight the individual journeys towards world-class manufacturing, commencing with a historical analysis of each organisation and its cultural roots and moving through the various development phases towards the final analysis of the case studies at the end of 2005. The historical development models will be compared and contrasted, with significant focus upon the "lead methodology" employed and the terminology prevalent in the case study. This element forms the first of three development phases in the key case study, building from the cultural foundation of T.Q.M. towards the Lean Sigma development period and on towards the end goal of the change management team.

The second phase examines the recent development trends in the case study and the integration of the key tools and techniques of Lean Production, Six Sigma and any other relevant methodology discovered in the course of the study. The author subsequently attempts to place this activity into the context of the Lean Sigma development process seeking to understand the cultural standing of the techniques employed and the interface with the "lead methodology" in place in the case study.

The third phase focuses upon the management visions of the future in the case study and the relevant milestones projected by the practitioners involved in the transformation process. The performance metrics are considered, with a view to identifying any changes that may be evident between the three phases in each

organisation. Company-by-company comparisons with the other satellite studies are considered and evaluated whenever possible.

Conclusions have been drawn from the development paths undertaken by each case study and the performance levels achieved. A number of essential elements are identified from the migration paths and a proposed roadmap is projected from the information gained from the case studies. The key phases can be defined as a study of the past, present and future of a significant case study supported by a number of satellite studies, with the significant aims of the project being defined as follows:

- **Developing a Critical Mass of Knowledge** – focusing upon the industrial development of the western manufacturing industry, studying the key development steps in its progression from craft to mass production. This activity is primarily focused upon the literature review and the general studies conducted throughout the research process.
- **Developing a Perspective on the Migration Paths** – focusing upon the core case study and a series of satellite studies to highlight the individual development paths, commencing with a historical analysis of the organisation and its cultural roots and background. The case study process throughout the period of analysis has provided the opportunity to review the individual development methodology employed by each of the case studies, allowing a unique insight into the critical success factors and stumbling blocks encountered along the way.
- **Studying the Individual Development Trends** – to be found in place in each case study and the integration of techniques that form the current management manufacturing improvement plan. Outlining the status quo in force at the moment and critically assessing the current performance metrics in each of the studies.

- **Defining the Management Vision of the 'Future State'** - of each case study organisation highlighting the step changes identified to achieve the proposed management vision of the new organisation. Critically assessing the timings, introduction programs and resource plans to deliver the proposed vision of the 'Future State' of the Case study.
- **Pulling Together the Essential and Common Elements Identified by the Research** – drawing the highlights and conclusions from each case study migration path with a specific focus upon the common elements or shared themes.
- **Defining the Critical Success Factors** - in evidence in the longitudinal research process. An equal weight has also been applied to the identification of common failings and problems throughout the research.

The research aims to reflect upon the findings from the key case study and the satellite case reviews, comparing and contrasting the approaches taken towards a shared vision of world-class manufacturing. This element of the research activity will aim to place the study into perspective with regard to the mass of industrial changes witnessed over the last seven years in Western European manufacturing. The literature review in the following chapter describes the knowledge gleaned from the industrial development in this subject area over the last hundred years, giving historical context to the changes witnessed. The author will attempt to follow the migration of the "state of the art" techniques as they evolve and are replaced by the next phase in the iterative development process. One constant in all of the change witnessed is the relentless pace of progress; Toffler (2000) believes that if anything, the pace of change has accelerated beyond the realms of considered strategic decision-making.

The study commences by examining the development of the Lean Production (L.P.) manufacturing process, which is considered to be an evolution from the craft assembly techniques that established the automotive industry over 100 years ago. The discussion will then progress through Fordism and the mass production techniques, which were much in evidence in vehicle assembly from the 1920s onwards and came to dominate the theory of manufacturing engineering excellence for the majority of the last century.

The research follows the historical migration from labour-intensive manual assembly and individual, one-off tool-making skills through to the work-study orientated mass production flow assembly process we associate with Henry Ford. The study will then follow the development of L.P. from its embryonic roots in the Toyota manufacturing system of the 1950s, highlighting the evolution of the Time Based Manufacturing (TBM) strategies that Ohno (1988) and Shingo (1985 1986 1988) developed at Toyota. It will then move on to the more recent improvement techniques, such as Kaizen improvement techniques (Sharma 1997, 2000), Oakeson (1999), Shinohara (1998) Sobek and Ward (1996), and thence to the standards of manufacturing performance achieved in the "Best in Class" of the automotive sector, as highlighted by the global automotive research work, "The Machine That Changed the World" (Womack, Jones and Roos 1990) and more recently by the work of Moozakis (2002) and Dawson, Armstrong, Muller and Welch (2002), who focus on a number of current automotive manufacturing trends. The technique we have come to accept as Lean Production has undergone a continual evolution over the last fifty years from its roots in the manufacturing engineering department of Toyota (Ohno 1988, Shingo 1985, 1986, 1988,) and has spread globally in the last five decades. Significant efficiency

improvements have been realised over this period within the arena of quality and quantity per worker and although the technique of Lean Production developed in the automotive sector, it has proved equally applicable across manufacturing sectors in the western manufacturing world (Womack and Jones 1996).

The study then reviews and considers the parallel development of the statistical management technique, Six Sigma (SS), from the early introduction of statistical management, building on the works of Gilbreth (1911, 1912) and culminating in the individual problem-solving tools and the development of the project management process of Six Sigma at Motorola (Breyfogle 1999, Harry and Schroeder 2000) that evolved into the comprehensive company-wide statistical improvement methodology established in the 1990s in multinationals such as General Electric (Welch 1996, Henderson and Evans 2000). S.S. can be considered as a more statistical and technically more challenging process than Lean Production, with its advocates viewing L.P. as a suitable approach for basic development but faltering somewhat at the 3-sigma development stage (Harry and Schroeder 2000). The process of S.S. developed through economic necessity in the Motorola Corporation in the 1980s (Lavigne 1996), as cost and quality issues prevented the company from competing with the Japanese electronic giants employing Lean processes. The turn-around in Motorola's financial fortune was well noted by the CEOs of corporate America, who were facing similar competitive threats from an increasing number of global competitors. This resulted in the process of S.S. becoming the tool of choice to defeat the Lean approach of Japanese manufacturing.

The third stream of thought highlighted in the literature review process is the recent amalgamation of the two approaches into the Lean Sigma (L.S.) initiative (Smith 2001; Smith and Beal 2001). The present research reflects Lean Production as the original thesis, Six Sigma as the antithesis and Lean Sigma as the synthesis of the two techniques. Lean Sigma (L.S.) can be defined as the L.P. assembly processes combined with the essential control and problem-solving techniques of S.S. (Lucas 2002 Dougherty 2000). The skills, project management and process improvement activity have become moulded together into the technique we now know as L.S. (Hoerl 2001). With the introduction of the tools and techniques of S.S. a broader improvement approach is attained, supported by the introduction methodology developed in the early S.S. organisations, Lean Sigma is gaining pace in the United States and is also now gaining a foothold in Western Europe. The literature review has highlighted two significant sub-themes, (1). Agile production can be considered a more customer-focused development of L.P. and (2). Build To Order, manufacturing to a customers specific requirement:

1. **Agile Production** - attempts to focus on the delivery of continual customer satisfaction rather than on the continual quest to reduce waste in the system, and as such, shares many basic principles with the T.Q.M. systems of the 1980s and 1990s. Agile production attempts to react swiftly and flexibly to customer demand, even if this requires additional stocking of products or components to satisfy customer requirements.
2. **Built-To Order (BTO) Production** – 'Late Point Identification' and 'Mass Customisation' are additional threads to the research with a technology-based approach to the delivery of customer requirements through the use of late-point completion or late-point product identification of customer specified

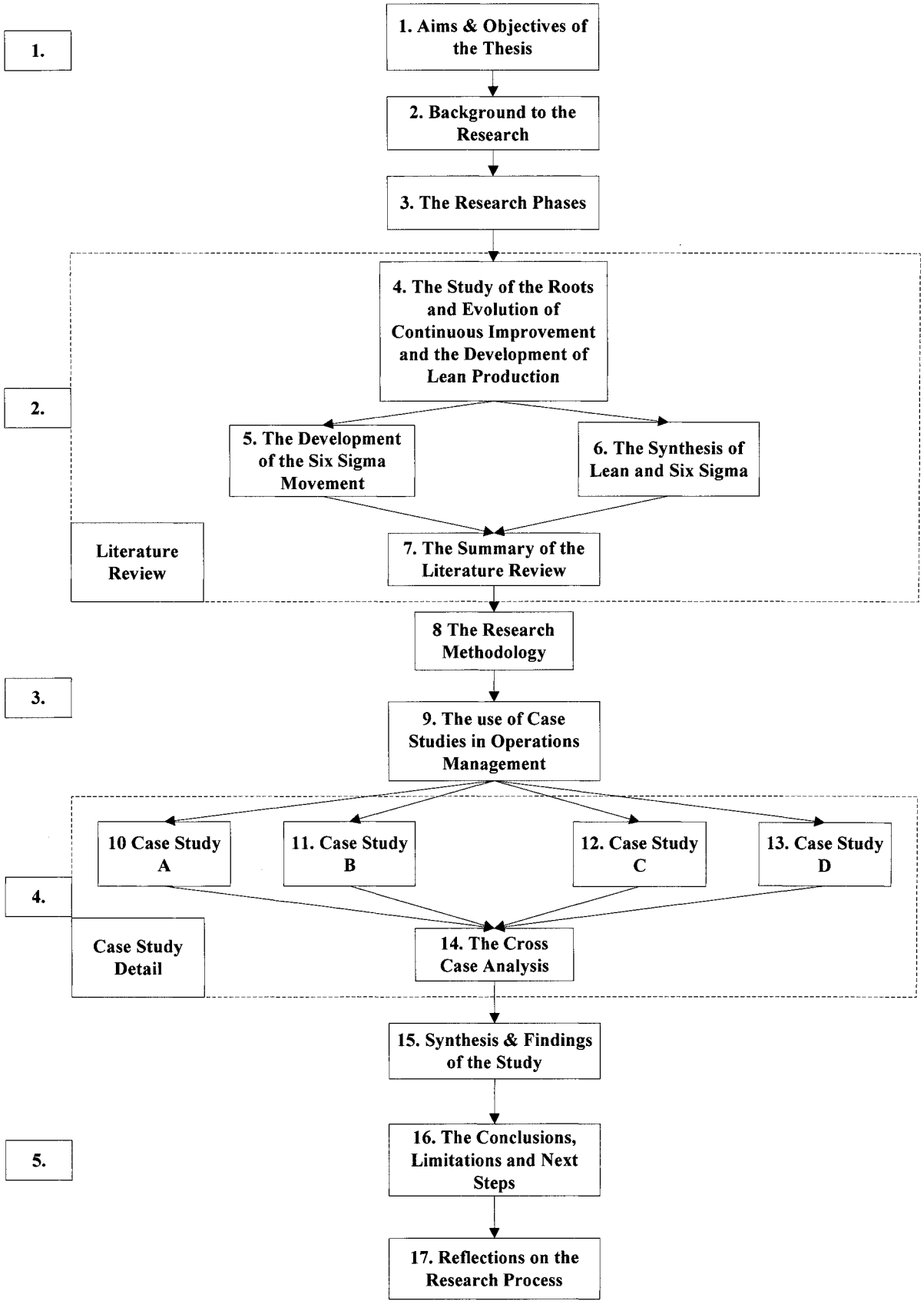
products. The technique has been pioneered by the likes of Dell Computers, and it has found much favour in the technology-based, electronics industries.

1.6 Overview of the Thesis Structure

The thesis is structured to fall into five logical research areas and a flow chart has been constructed to highlight the sequential nature of the research activity. The research areas are structured as follows:

- **The Aims, Objectives and Background of the Research** – focusing upon the motivation, content and structure of the thesis.
- **The Literature Review highlighting the three phases of Continuous Improvement** – the evolution of Lean Production, the development of the methodology of Six Sigma and the synthesis approach of Lean Sigma.
- **The Research Methodology** – highlighting the use of case study methodology in the process of the research activity.
- **The Case Studies** – presenting an overview of the findings of the core case study and the satellite studies, inclusive of the cross case analysis.
- **The Findings and Conclusions of the Research** – highlighting the synthesis of the case study findings and the critical success factors and conclusions.

FIG 1.6.1 PROCESS OVERVIEW OF THE THESIS STRUCTURE



Chapter 2. 0 - Continuous Improvement: Origins and Evolution

"I have no intention of criticizing Henry Ford (1886 – 1947). Rather, I am critical of Ford's successors who have suffered from excessive dependence on the authority of the Ford system precisely because it has been so powerful and created such wonders of industrial productivity. However, times change" - Taiichi Ohno 1988

Ohno (1987) reserves his criticism for those who bought into Ford's methods, then failed to develop them. They failed to evolve and grow, and thus commenced the decline of the western world's automobile industry (Womack, Jones and Roos 1990, Womack and Jones 1996). Ohno (1987) recognised the need to take Ford's breakthrough and build a lean, time-efficient, quality-focused process on the foundations of mass production. Of all the key themes (Lean Production, Six Sigma and Lean Sigma) examined in this research process, Lean Production (L.P.) is the most mature, having undergone a degree of evolution and development over the last five decades. The process developed out of the continual quest for waste eradication in post-war Japan, becoming the Lean system we recognise after much trial and error, over many generations of Continuous Improvement (C.I.) development at Toyota (Shingo 1985, 1986 and 1988, Imai 1997, Ishikawa 1985, Monden 1993) and subsequently through the industries of the western world (Womack and Jones 1996).

A number of the techniques we now recognise as fundamental to the L.P. process developed from the pioneering work of Taylor and Shewart in the 1920s and Deming and Juran (Bendell 1990) in the 1950s, with many additional contributions in the second half of the last century. The influences of early T.Q.M. pioneers, Edward Deming and Joseph Juran still run deep in Japanese industry (Jack 2001). The Deming award remains the most prestigious award for quality in Japan, while Deming himself was awarded the order of the Sacred Treasure by the Japanese Emperor Hirohito in

1960. The development of quality in Japanese industry owes a great debt of gratitude to the post-war American pioneers. The Deming 14-point plan (Jack 2001) set the tone for much of the post-war continuous improvement activity.

The term "Lean" is coined to represent a manufacturing methodology based upon Toyota's "Time Based Manufacturing" (Imai 1997; Ohno 1988; Sekine 1992; Shingo 1985, 1986, 1988; Shinoharo 1988, Suehiro 1992) strategy and encompasses a selection of processes and tools of continuous improvement (Ishikawa 1985; Suzaki, 1993, 1987; Taguchi 1986, 2000). The methodology commenced in the automotive industry, with the automakers proving to be the catalyst of much of the development of L.P. The works of Ohno (1988) Shingo (1985, 1986), Balakrishnan (2002) and others highlight the development of the Toyota T.B.M. system from idea germination to system maturity. The Toyota initiative is company-wide and succeeds on the broad front of employee involvement at all levels (Shimbun 1990), striving to achieve small, incremental improvements, "inching the business forward". The case study performed by Elsey and Fujiwara (2000) concluded that the "Kaizen" workforce is very enthusiastic, committed and dedicated to the success of the Toyota manufacturing system. The works of both Shimbun (1990) and Elsey and Fujiwara (2000) highlight the essential need for operator involvement in the LP process.

In reviewing the evolution of the L.P. development process over the last 50 years, the most appropriate starting point from which to give a holistic picture of the organic growth of the process is with the Toyota system (Monden 1993). The incremental progress in the early stages at the Toyota manufacturing plants in and around Tokyo gives an insight into the L.P. ideas germinating in the minds of the likes of Ohno

(1988) and Shingo (1985, 1986, 1988). The concept evolved in a number of significant Japanese manufacturing companies, though Toyota championed the development we have come to regard as L.P. The unique environment in Japan after the end of the Second World War fostered a fertile medium for growth, and once this was combined with the culture of incremental innovation, a powerful improvement process was unleashed. As we study the development of the process we see significant automotive content in the growth of the processes of L.P. and a distinct replacement of the "Old World" order. The design, development and construction of the automobile would never be the same.

The literature highlights (Womack, Jones and Roos 1990) three distinct phases of automotive development, understood as Craft Production, Mass Production and Lean Production, which all bring fundamental manufacturing process changes in each of the significant development phases. Each initiative can be regarded as a manufacturing *"breakpoint"* (Strebel 1998) that entirely changes the perspective for the competition. McCallion (2003a) feels that Ford's Dagenham site has come a long way from its openings in 1931 and represents many of the best in class initiatives. In the view of plant manager Mike Harvey, "the new Dagenham site seems to be showing the way forward for British manufacturing, just as Ford did when it introduced mass production to the UK". The Ford site progressed from its embryonic roots in the Ford mass production system to the development of a L.P. methodology in the 1980s and 1990s, stimulated by the successes of other US auto manufactures, highlighted by Rushwin (1996), who were following the Toyota manufacturing model (Taylor 1997, Balakrishnan 2002) and closer to home, the success of Nissan (Muuzakis 2002, Lydon 1990, Patton 1997, Dawson et al., 2002).

2.1 Commencing with Craft Production

Automobile production at the turn of the century was predominantly based around small-scale individual carriage builders that had developed from related industries (Womack, Jones and Roos 1990), with Panhard et Levassor's development from metal cutting manufacturing equipment and BMW, originally known as Bayerische Motoren developing from airplane engine manufacture, being typical examples. The volume was small and teams handcrafted individual vehicles to satisfy discerning customers' orders. The market for automobiles was localised and little cross-border trade was performed. Vehicle cost was a significant barrier to the growth of the industry and only the most affluent could afford to become car owners. For the early innovators, the product was not only expensive but at the same time suffered from significant performance and reliability issues, reflecting the infant nature of the industry. One of the basic benefits of mass production is price reduction as volume increases. This is not applicable to the craft-based organisations. Orders for thousands of vehicles would probably be in line with the cost for orders of tens. The very nature of the craft manufacturing process worked against the economies of scale that proved so beneficial to the mass production market. Womack, Jones and Roos (1990) define the key characteristics of craft production as follows:

- **Highly Skilled Workforce** - of craft based workers, many progressing through a general apprenticeship of design, machining and fitting and gaining a broad base of mechanical knowledge.
- **Decentralised Organisations** - centred within a single city, subcontracting to small machine shops with an owner / entrepreneur contacting customers, employers and suppliers.

- **General-Purpose Machine Tools** - being utilised to perform drilling, grinding, and other operations on wood and metal, with little purpose-built machine tooling.
- .**Very low Volumes** - of less than 1000 per year, with very few being made to the same design and no two being exactly alike, as craft techniques produced inherent variation. The automobile was an exclusive luxury item and usually built to a unique specification, with a degree of interpretation from the artisans on each individual assembly.

This is well reflected in Henry Ford's early production line for chassis assembly, which consisted of a single man taking over twelve hours to construct a single chassis (Brinkley 2003). The transformation over eight months of standardisation and labour study resulted in a cycle time of ninety-three minutes per car. Henry Ford made the transformation after having the assembly line idea planted in his mind as he watched a conveyor of beef carcasses progress through a Chicago slaughterhouse. Ford adopted the conveyer line idea and worked to replace the individual craftsman with a considered introduction of repeatability of worker movement and actions and a new simplicity of process.

In contrast to the accepted wisdom of Ford pioneering the mass production movement, the American Automobile Association (2004) considers the development of Ransom E. Olds' Detroit factory as the first step towards mass production from the craft-based production facilities. By 1900, fewer than 10,000 cars had been manufactured globally, and during its first year of operations in Detroit (1901), the Olds Company produced 425 individual cars. The 3-h.p., curved-dash Oldsmobile thus became the first real success among commercially-sold U.S. automobiles. The

first steps towards mass production had commenced, with Ransom E. Olds becoming the first automobile manufacturer to gear up for genuine volume production.

2.2 The Birth of Mass Production

The 1920s witnessed a breathtaking manufacturing breakthrough, with the birth of a new assembly concept that would change the world of manufacturing. Significant steps were taken away from the old order of the craft-based world of construction techniques. Henry Ford coined the term "Mass Production" in the 1926 Encyclopaedia Britannica, with others referring to it as "Fordism". His famed quotation, 'you can have any colour you like as long as it is black", became a mass production slogan that came to represent the methodology and spirit of the movement.

The public appear to have understood and warmly welcomed the new mechanisation, fully accepting Fordism (Brinkley 2003) as progress. The manufacturing process had developed into a constantly running flow line, churning out vast quantities of the same automobile to the same specification and in the same colour. Ford opened the original "Tin Lizzie" manufacturing plant in 1913, producing one Model T every 93 minutes, a reduction from the 728 minutes per car that had previously been required. By the time the last Model T was built in 1927, the company was producing an automobile every 24 seconds, and the age of mass production had begun. The increase in mass production efficiency allowed Ford to undercut much of the market, with the Model T's price dropping from its original 1908 cost of just under $1,000 to under $300 by 1927.The birth of the model T Ford made the automobile available to a totally new market. The selling price began to drop as a result of the larger quantities of vehicles

manufactured by the more efficient, less craft-orientated process. The days of individual craftsmen in the industry were numbered.

The individual production-line operators became true specialists as opposed to the historical trend of craft production generalists, each manning an assigned post on the assembly line, tied to an individual task. Many of the developments were founded upon of F.W. Taylor's (1911) principles of scientific management and the studies of Frank and Lillian Gilbreth, "Motion Study" (1911) and "A Primer of Scientific Management" (1912). Ford built upon these studies and theories and embarked upon mobilising the industrial world. Car production would become a significantly cheaper and more efficient process, and the first steps were taken towards the development of a global automobile business.

Mass production has come in for criticism as manufacturing technology has developed. Nielson and Simons (2000) regard the concept of the production line "Push" system as one of the greatest contributors to waste and over-production, as the system itself quested for greater quantities of automobiles to roll off the end of automated lines, satisfying an ever-growing demand for cars for the masses. The "Push" concept worked well in a time of underproduction and constantly expanding markets. Western consumers had a new level of disposable income and the automobile figured high on the list of desirables. Monden (1993) highlights that the challenge for the automotive industry, as the market reached saturation, would be to develop a Lean "Pull" system that promoted efficiency and the reduction of waste. This problem would be worked upon from the 1950s by a number of Japanese production engineers in a small truck-making firm that was to become the Toyota Manufacturing Company. Richard Cooney (2002), argues that both the batch and craft

approaches are still applicable to certain elements of the luxury automotive and specialty component sectors. He feels that the constant quest for flow blinds many organisations to the potential benefits of using a combination of craft and lean skills. Cooney concludes with the thought that "Lean" is not a system with universal applicability and it provides only a partial model for manufacturing systems.

2.3 Learning to be Lean

Japanese industry faced significant problems at the end of the Second World War. With much of its infrastructure destroyed and its people conquered, the development of a globally dominant auto industry looked to be a distant dream. Bendell (1990) highlights the contribution that Deming, Juran and Feigenbaum made to the development of the Japanese manufacturing sector, kick-starting the transformation with the delivery of theory and knowledge. All three quality giants travelled to Japan and helped with the supply of the all-important knowledge of the new way. Ohno and his peers accepted the gift and supplied the passion required to transform the Japanese and global auto industry. LP was driven to a large extent by the development within Toyota of a time-based manufacturing process that aimed to drive out waste (*muda*) in the manufacturing system and looked afresh at the total cost of production (Monden 1993). Its aim was to increase flexibility and up-time whilst delivering a customer-focused product. The approach reflected a return to some of the small-scale advantages of craft production, combining these benefits with a more cost-effective and time-balanced approach than the mass production system long espoused by Ford. The development of L.P. in the automotive industry progressed into many areas in the 1980s and 1990s, and the global automotive case study "The Machine That Changed

the World" (Womack, Jones and Roos, 1990) and "Lean Thinking" (Womack and Jones, 1996) initiated the process of convincing many of its applicability outside Japan and also of the opportunities and potential available to non-automotive industries.

The advantage in productivity shown in the early 1990s is still broadly evident, as seen, for example, in the work of Hill (2000), who highlights the significant advantage still shown by the Japanese Lean Manufacturing base, or the more recent transitions towards a Lean culture and assembly system (Delbridge and Lowe 1998). The work of Womack Jones and Roos (1990) explained the improvement process behind the success of a number of car manufacturers and highlighted the potential of L.P. for other industries. They also bring into sharp contrast the performance of a number of European and American automakers, who are still pursuing the goals of mass production. Rushwin (1996) highlights the adoption of the concepts of L.P. by Chrysler, one of the 'old order' of American automakers.

Womack and Jones continued the movement towards Lean with the publication of "Lean Thinking" (1996), an in-depth study of the companies implementing L.P. outside of the automotive industry. Non-automotive businesses witnessed changes in the transitioning American and European automotive companies in the late 1980s and early 1990s and commenced the migration towards Time Based Manufacturing solutions. Boeing introduced the implications of L.P. into its corporation, with the American consultant Leland Williams proclaiming "'the Machine that Changed the World' (1990) gave us a road map to competitive advantage". The consultancy Achievement Dynamics Inc. helped to introduce the strategy into Deer and Co, Exide

Battery and Daimler Chrysler. They consider L.P. as a systemic approach: "it's about rules, it's about thinking, and it's not about tools". This approach is in contrast to a number of strategies that focus upon Key Tools and have driven in the initiative as a series of significant techniques. The author feels that they are looking to follow the process with the methodology at a later date, considering LP as a menu from which individual items may be chosen. In contrast to this approach, Friedli (1999) is of the school that warns against the individual tool-pushing strategies. Reflecting on the dangers, Friedli suggests that, "the half hearted approach could do more harm than good". The dilution of the LP structure by those wanting to perform instant change has become known as the blitz approach (Brennan 1998, Sheridan 1997, Patton 1997) or "Kamikaze Kaizen". Friedli (1999) argues that this approach will have a long-term detrimental impact to the acceptance and adoption of the L.P. process.

The cultural differences between East and West are reflected in this polarised argument, with the evolutionary Japanese approach to L.P. standing in stark contrast to Friedli's (1999) one-week wonder workers. Steve Brennan (1998) comments about the positive nature of this "jump start" approach while reviewing a four-day workshop at Perkins Engines performed by consultants TBM. Anand Sharma (1997, 2001), one of the leading international practitioners in this field, headed the program. O'Hanlon (2003) highlights the difference as a frame of mind, with the time-bound blitz representing a surgical insertion of the Kaizen spirit, rather than the systematic introduction and acceptance of the way of life. If the surgical approach is to be introduced into a manufacturing facility, the management team must accept that small islands of improvement need to be supported and encouraged. They should not be left as a reminder of the Kaizen activity and as a showcase for the technique; this cannot

become a box-ticking activity. The author's thoughts are supported by Friedli (1999). The author has participated in a number of "Breakthrough Kaizen" events with Anand Sharma and his team, both internally and externally to his own company, and also has experience of leading external teams, commencing at one of the case studies in Oxford in 1998/9 and an electronics manufacturing plant in 1999. The initial five-day program is designed to deliver significant efficiency and quality improvements, reduce floor space, and engage worker participation in a "Crash Kaizen" course. Browning (2003) highlights the success of "Crash Kaizen" at Rosti, Scotland, with the first Kaizen blitz raising the plant's productivity by 77% and reducing on-site stock holding by 93%.

The author feels that organisations that make significant improvements through "Kaizen Blitz" activity in the first instance have structured this activity as a kick-off element of the L.P. process. Companies that have succeeded with the short-term initial exercise, in the author's experience, intend to implement a full L.P. rollout plan and utilise the initial workshop as a management and employee education activity. The initial blitz is thus only a forerunner to a complete package of tools training and process reviews, structured behind the initial activity. The failures reviewed by the author often did not grasp the concept of Kaizen as a life-style change: the four or five-day blitz activity course does not, in its own right, complete the transformation from flabby European manufacturer to Lean world-class organisation. The conflict between Friedli (1999) and Brennan (1998) reflects a number of the differences between the commercially motivated concerns of independent consultants, looking to introduce the concept of L.P. as a financially attractive proposition, easily adaptable to Western organisations. Friedli (1999) introduces the downside of this approach and

advocates that companies should consider the long-term ramifications and commitment behind L.P. It is formed mainly from developments to the Toyota methodology, although it has its own internal conflicts in academic circles, none more so than the Lean vs. Agile debate.

2.4 Agility

Lean Production, to some, is old news, yesterday's answer to the problems of the day before. To respond to change, a number of authors believe that being Lean is not enough, suggesting that we need to become Agile. Ross (1994) suggests that businesses should strive towards the development of a dynamic, re-configurable organisation based on the foundations of Leanness. He suggests three pillars:

1. **Commencing with a Lean Production Foundation** – established around the fundamental elements of the time based manufacturing practices.
2. **Progressing Towards the Establishment of Concurrent Product Development Cycles** – linking the design and manufacturing elements of the business and ensuring fluid development activity and seamless linkage to the manufacturing facility.
3. **The Development of a Strategic Partnership Approach** – in all development and support areas.

Ross (1994) and Christopher (2001) also define the need for advanced information database systems to control the development and manufacturing processes as being essential in the initial steps towards an Agile business in a volatile market place. The need to satisfy the customer with a specifically tailored product may not be a business strategy so much as a core business competence. Dove (1997) defines Agility as "being proficient at change, allowing the organisation to do anything it wants to do

whenever it wants to". Christopher (2001) and Christopher and Towill (2001) highlight that Agile performance improvements result from a flexible, customer-focused approach that takes the L.P. model and develops a quick, customer-centred response. To make the Agile model work, a number of management practices require development. In terms of the previous Lean culture, Hooper, Steeple and Winters (2001) believe that its costing and management accounting systems require significant development in order to provide a total solution system fitted to an agile environment. Alvin Toffler (Daly 2000) warns against the substitution of strategy by Agility, noting that being purely Agile cannot replace the need for business strategy. The Agile business is not so focused upon the total elimination of waste and tolerates some fat as a sacrifice towards customer order fulfilment. Whitehead (2000) contrasts the two approaches and highlights the three key principles of Agility as:

1. **Customer Focus** – Aim to instantly meet the needs of your customers, do not focus just on the elimination of waste.
2. **Seamless Links with Suppliers** - Develop flexible and fluid relationships with suppliers to capitalise on market opportunities.
3. **Become Less Focused on Stock Levels and more on Customer Needs** – The elimination of stock along the L.P. principle of Just In Time (JIT) should be considered less important than satisfying the customer.

Aitken (2000) has constructed a simple table (2.4.1) to compare the Lean and Agile approaches in a custom factory; this case study covers a manufacturer of lighting equipment in the UK. He concludes, "Through the complimentary partnership of Lean and Agile practices the company is gaining a significant competitive advantage".

Table 2.4.1 Aitken (2000) – Comparison of Lean and Agile Custom factory		
Approach	**Lean**	**Agile**
Product	Standard	Customised
Product Creation	Market Demand	Customer Specified
Product development	Pre-defined and Codified	Structured but Experimental
Quality Control	ISO 9000	ISO 9000
Manufacturing Process	Pre-defined	Order Specific
Manufacturing Operations	Lean	Lean and Agile
Professional Stimulus	Performance Improvement	Creativity
Supplier Base	Narrow	Broad
Component Procurement	Kanban	Discrete Orders
Component Drawings	CAD	CAD / Sketches
Supplier Product Development Input	Design Stage	Concept Stage
Supplier role in Product Development	Used as Consultant	Interpretive
Knowledge Exchange	Codified	Codified, Tacit
Component Tooling	Hard, Expensive	Soft, Low Cost
Tooling Lead-times	Months	Days

Aiming to meet the needs of the customer, and not just eliminate the waste in the system should be followed by both Lean and Agile organisations, it is not the exclusive domain of either school of thought. Correct usage of tools such as Quality Function Deployment (Akao 1998) should, at the design stage, deliver a customer-focused product, supported by swift and decisive responses to customer need changes (Lancaster and Hicks 1995), through the various tiers of production. The reverse logic would suggest that Agile businesses do not need to work towards the elimination of waste: that is evident in the organisation.

The relationships developed by Lean organisations between links in the supply chain have historically tended to be long-term partnerships; with significant sharing and mutual aid, they are reflective of the Agile model projected by Ross (1994) in the early 1990s. Christopher and Towill (2001) consider that the Lean and Agile supply chains are not mutually exclusive paradigms and see many benefits from a

hybridisation strategy. Rankey (1998) comments upon the fixed and static nature of some Lean supply chains and views the move to a more dynamic model as essential in an Agile environment. The short-term element of the Agile relationship and the development of a more contract-based process could impact upon the responsive nature of the mutual arrangement. The author can see little benefit resulting from this, with many of the significant gains being lost as the relationship breaks down.

In financial terms, Nissan's association with Renault highlighted that a number of suppliers no longer performed in a cost-efficient manner and the focus on quality and supplier relationships had a significant additional cost burden. This should be regarded as resulting from neither a Lean nor an Agile orientation, but purely that good business and commercial practices, result in a cost-effective result for the buyer of a product or service that is "fit for the purpose intended". The focus on "Just In Time" should not distract from the focus on customer needs, and the two principles require a degree of balance. 'Mass Customisation' as a process has long been pushed by companies like Dell computers. Hall and Rhymer (2000) view 'Mass Customisation' as "offering unique products of high quality at low cost, which satisfy the consumer's needs. To realise this concept a choice of diverse specifications and the ability to change a products profile quickly to suit a specific need is an essential pre-requisite". Dell epitomised this dream (Vincente 2001) of low to zero inventory, with net margins in 1998/9 of almost twice that of its key competitor, Gateway.

A number of Lean automotive manufactures consider themselves as competent at 'Mass Customisation' in tandem with J.I.T. Moozakis (2002) highlights Nissan's quest to be the first major automaker with web enabled Build–To-Order (B.T.O.)

manufacturing capability. Nissan intends to establish a Dell-like custom manufacturing system; its development process commenced in mid-2003. Moozakis (2002) comments upon the advantages Nissan has as a result of its already Lean manufacturing model and quotes a Ford spokesman: "Build to Order is a dream we would all love to happen, but the Nissan claims invite a lot of scrutiny". Hall (2000) highlights the fact that the auto market is undergoing a period of change and the Lean Manufacturing organisations look best able to exploit the change. The pace of model changes and increasing variety is confirmed by Holweg and Greenwood (2000): "The conclusion that can be drawn from the data is that the rate of innovation is clearly accelerating with more models offered, that remain on the market for shorter periods than in the past. The rate of new designs and innovation in the automotive market has increased significantly (Dawson 2002), and the vehicle manufacturers will have to face the challenge of responding to customer demand and competitors' action in an ever more responsive fashion in the future, whilst being constrained at the same time by much shorter sales windows and lower overall volumes per model to cover their costs." In 1999, 70% of all volume brand vehicles were sold from existing, pre-produced stock holdings in the UK market place, (Miemcyzk and Holweg 2001). In the author's view, the compatibility of B.T.O. and L.P. models will become increasingly attractive to the manufacturing organisations of the west, reflecting industries such as computer manufacture and the lead set by Dell Electronics.

The history of manufacturing in the last century is not overflowing with tales of ponderous, slow-moving, non-customer-focused businesses that set the world alight with commercial success, the need for a degree of Agility is a given. A thread of the need for Agility in the manufacturing system runs through the work of many Lean

Production supporters with the work of Schroeder (2000), although structured to review organisational strategy, favouring an Agile and fast-moving approach to the market opportunities of today. Commentators such as Peters (1987, 1992), Browning (2003) and Aitken (2000), argue for an Agile approach and offer a flow of strategic advice to get close to the customer, reduce product development timescales and look towards innovation. Joiner (1994) advocates rapid improvement and learning processes, listening and responding to the voice of the customer via strategic customer-focused initiatives. Peters (1987, 1992) bases much of his work around the process of Agility and the needs of the customer, with service being delivered in a timely fashion. He reviews the stripped-down management of ABB (Peters 1992) and the revolutionary business structure in place across its global operations. The T50 program, launched in 1992 at ABB, was aimed at cutting in half the order-to-shipping cycle time, structuring the business to be able to meet the requirements of the new market. It also had implications for the customer interface, as speed is of little consequence if we are not close enough to the customer to understand real customer requirements.

ABB would become one of the first companies to adopt the principles of S.S. after the success of Mikel Harry at Motorola. Mikel Harry and Richard Schroeder joined ABB in 1993 and commenced to roll out the process of S.S. implementing the program developed at Motorola. ABB are often considered as one of the pioneers of SS, though if we look deeper we can see that they have significant vision and depth of management, and that a very progressive strategy was already in place prior to the entrance of Harry and Schroeder (2000). This highlights the complexity in organisations like ABB and the over-simplification of regarding organisations as

following one distinct line of thought. No initiative develops in a vacuum, and ABB is a good example of a migration path that builds upon solid strategic foundations and makes sophisticated use of a number of world-class techniques.

C.I. labels are at times added to initiatives to communicate the direction to external areas, the stock market or Wall Street. The emergence of General Electric (G.E.) in the USA as a significant S.S. player added credibility to the initiative and put pressure upon any organisation proposing to follow an alternative initiative. Peter Hines (Hines and Taylor 2000) from the Lean Enterprise Research Centre at the Cardiff Business School regards the Agile approach as a re-branding of old L.P. ideas to get a product on the market. Hines and Taylor build upon the late 1980's work of Lucas Industries and consider three types of production as follows:

1. **Runners** – Items manufactured in large numbers in a continuous flow process with no variation (High Demand and Low Variability).
2. **Repeaters** – Goods produced intermittently in batches to a standard design (Medium Demand and Medium Variability).
3. **Strangers** – One-off, high-cost goods where there is a large degree of customer specification (Low Demand and High Variability).

In the application of L.P. the author recognises aspects of both approaches within the manufacturing plants of the case studies and considers them to be slight variations upon the theme of L.P. Inside one of the case study organisations, all of Cardiff's categories have been historically present, with a continuous flow of standard runners (consumer power tools) in high volume, as well as repeaters for unique market execution (high-value, low-volume workshop machinery) and strangers (one-off projects to supply branded executions with unique features and industrial design

changes). By the very nature of the challenge faced, the appropriate approach is selected to fit the project in hand.

The arguments between the Agile and Lean approaches remains academic in the main and of little concern in many manufacturing companies. The Agile approach reflects the introduction of a more strategic management approach with concerns outside of the L.P. heartland of manufacturing and can be considered as an extension to the time-based manufacturing systems of L.P. The majority of published material on L.P. is based upon the individual elements of the manufacturing process or the time-based nature of the assembly system (Shinohara Isao, 1988; Shingo, 1985, 1986, 1988; Shimbun, 1986, Keen 1996), with little published material to highlight the structured consideration of the external elements of business pressure or customer interface. The one conflict that the author considers significant is the never-ending search for system waste (*muda*) that is central to the L.P. process, but that could possibly result in an anorexic state if sight of the goal is lost; all L.P. businesses need to be mindful of the implications of this for the flexibility of their operating systems.

Carrie (1999) considers the key elements of Agility as the ability to rapidly alter production volumes and product specifications, and to identify and meet emerging customer requirements, adopt emerging technology and deliver the total service package, not just the physical product. Spring and Dalrymple (2000), in contrast, highlight a number of differing interpretations of the terms of Agility, Flexibility, Total Flexibility and Flexible Agility. They also quote Burgess (1994) in saying "there does not appear to be an identifiable manufacturing characteristic called Agility" despite the use of metaphors highlighting Sumo wrestlers and ballet dancers.

2.6 Lean Systems and Tools

Tom Peters (1992, 1997) paints a big picture of bright new beginnings and quantum leaps. He feels that incrementalism, evolution and Kaizen initiatives are yesterday's solutions. Peters (1997) advocates the acceptance of a strategic direction as opposed to a defined plan and tends to discuss solutions at a top level of detail, considering the incremental detail of Kaizen as dated. The literature reviewed on L.P. can be considered as dealing in the fine detail of incremental improvement that is of little interest to Peters and falls into the arenas of the manufacturing system approach or the teaching of individual tools within the system. The full Toyota system is reviewed by one of its key players in the work of Ohno (1988), which maps individual developments over the last 50 years. This is followed by many individual works on Toyota's manufacturing system (see, for example, Balakrishnan, 2002; Sobek and Ward, 1996; Stahl 1994; Taylor, 1997). The development and progress of other businesses has been studied against the results of Toyota, with a particular frame of reference upon the Time Based Manufacturing system as an element of the total system.

Womack and Jones (1996) frame the development of Lantec, a manufacturer of stretch wrap machines, along L.P. lines, and also review a number of business models outside of the automotive sector in their book Lean Thinking, which highlights the system's broad appeal and application. They review 50 different Lean businesses, focusing on the key threads of identifying customer value and the impact of the pull of the customer. They attempt to build on the waste-reduction process of L.P. with the identification of the next level of value stream improvement. Hines and Taylor (2000) draw five key principles from the work of Womack and Jones (1996):

1. **Value Identification** - specify what does and does not create value from the customer's perspective and not from the perspective of individual firms, functions or departments. Hines and Taylor consider the identification of value as a prime step in the improvement process.
2. **Waste Identification** - identify all the steps necessary to design, order and produce the product across the whole value stream to highlight non-value-added activities or waste. This step should be considered in parallel to the identification of value in the system.
3. **Facilitate Flow** – focus the business upon making the product flow. Driving those actions that create value and facilitate flow without interruption or detours or deviation.
4. **Make to Order** - only make what the customer pulls. This does not mean make what the customer wants, the production process should reflect the customers current pull requirements and drives the business to focus on the time phased manufacture and delivery of the requirements of the customer.
5. **Strive for Perfection** - by continually removing successive layers of waste in labour, material, time and product.

Ranjan (1998), in his attempt to bring the time-based manufacturing strategy up to date, set out to reveal the complexity of the system, highlighting the many elements and sub-systems that contribute to the total system. Suri (1998) and Monden (1993) help to clarify the many interlinked elements of this complex process that has simplicity and waste reduction as its goals. Imai (1997) focuses on the LP manufacturing system with Kaizen continuous improvement as the central improvement theme, highlighting the Kaizen aspect of the Toyota system as the driver for the many related elements of the system. In the author's view, this could possibly

over-simplify the overall complexities of the support infrastructure and the cradle-to-grave contribution for many additional areas. The Toyota system has been built from the ground upwards over fifty years, with many individual elements contributing towards the total system, such as:

1. **Product Design and the QFD Process** - delivering translation of true customer requirements through interpretation of customer wants and needs into finished products and processes (Akao 1998).
2. **Experimental Design** – used for process improvement and capability advancement (Bhota and Bhota 2000, Taguchi 1986, 2000).
3. **System Maintenance** – focusing business on overall equipment effectiveness and utilisation and maximising the benefit of machinery to the business (Suehiro 1992, Sekine and Aria 1998, Dwyer 1998 and Nakajima 1988).
4. **Quality Control and Product Consistency** – a key element of product delivery and customer satisfaction as well as allowing the manufacturing process to flow in a seamless fashion (Ishikawa 1985, Shingo 1985).
5. **Workplace Improvement and the "5 S" System** – founded on workplace management and workspace development principles to bring order into the individuals management areas (Kobayashi 1995, Shingo 1985).
6. **Product Standardisation** - a fundamental element of the design and manufacturing process and a starting point that aims to commence the Lean activity in the design phase (Nakamura 1993).
7. **Employee Involvement** – encouraged throughout the design and development path (Shimbun 1990, Suzaki 1993).
8. **Single Piece Flow** – inbuilt in all manufacturing systems to eliminate component build-up and reduce quality-related issues (Sekine 1992).

Behind the understanding of the entire umbrella initiative of the Toyota manufacturing system, a robust and detailed knowledge of the individual C.I. tools is essential (a summary of a number of key tool handbooks is provided in table 4.6.1). Among the significant individual tools, the design and development of a standard product offering, linked to the critical requirements of the customer, is a cornerstone of success. Nakamura (1993), Oakeson (1999) and Kobayashi (1995) focus their attention upon standardisation of the product design and manufacturing process. The delivery of consistent performance is to a large degree founded on workplace improvement techniques. Sekine (1992) extends this into the areas of U-shaped Cells and the need for single-piece flow to maintain the consistency of performance. The works highlighted can be considered as cornerstones in the L.P. process and essential individual elements of the Toyota manufacturing system. However, it is dangerous to attempt to cherry-pick the initiatives that we feel most comfortable with or those that are apparently the most applicable to individual issues that are currently being faced in the manufacturing environment. Hanson (1995) adds to the studies of Toyota and Nissan, as leaders in the field of quality and productivity. He examines the response to the economic recession, or *endaka,* faced by Japan between 1993 and 1995 and highlights the Lean methodology in practice in trying times. He highlights the ability of the Lean system to react to the challenges faced through the mid-1990s in Japan and in competition in aggressive global markets. Hanson (1995) comments upon the development process of Lean systems across the manufacturing business of Japan from a form of T.Q.M. (likened by Hanson to the development of a degree of mental fitness in the manufacturing business) to T.P.M. (likened to the achievement of physical fitness across the entire business), highlighting the continual need to evolve to meet the next challenge.

A summary of a number of key tools and processes is presented in Table 2.6.1

Table 2.6.1 Summary Table of Lean Tools and Processes

Author	Tool / Process	Area of Analysis
McDermott, Mikulak & Beauregard 1996	Failure Mode and Effect Analysis (FMEA)	Application of the FMEA process to product design and development, evolving from its roots in the safety hazard review process
Damelio 1996	Process Mapping	Development on systems thinking from the work of Geary Rummler
Shingo S. 1988	Non-Stock Production / Continuous Improvement	JIT / Non-Stock Production – The Shingo System for Continuous Improvement in manufacturing
Shingo S. 1985	Poka-Yoka and Source Inspection	Introduction to error proofing techniques and source inspection on assembly processes
Shingo S. 1983	Single Minute Exchange of Dies (SMED)	The development of quick change methodology alongside the understanding of internal and external time and the elimination of waste in the process
Dillon 1997	Mistake–Proofing	Development from the work of Shigeo Shingo
Nakamura S.1991	Process Standardisation	Development and maintenance of standard processes as a cornerstone of the Lean manufacturing process
Sekine K. & Arai K. 1998	Total Productive Maintenance (TPM)	Equipment management techniques for improved uptime in the Lean factory
Sekine K. 1990	One Piece Flow	Development of Cell manufacture and single piece flow work processes to improve productivity and reduce WIP and quality rejects
Akao Y. 1988	Quality Function Deployment (QFD)	The integration process of customer requirements with the design process
K. Ishikawa 1985	Quality Control From A Lean Perspective	Basic Quality Control techniques from the perspective of the Lean Manufacturing environment
Brown L. A. 1991	SPC Introduction	Statistical Process Control introduction and implementation handbook
Oakland J. S. 1990	SPC Introduction	Statistical Process Control introduction and implementation pamphlet produced by the DTI
Suehiro K. 1987	Continuous Improvement	An introduction to the principles of Continuous Improvement techniques and processes
Suzaki K. 1992	Automation in the Lean factory	Reduction of stoppages in the Lean Production facility
Suzaki K. 1993	Empowerment for Cont, Improvement	Worker relations and empowerment in the Lean factory
Shinohara I. 1988	JIT and Lean Production Systems	Early introductory work on the implementation of JIT into a lean system
Monden, Y. 1993	Toyota Production System	An Integration approach to Just In Time in the manufacturing environment with a systems view of the Toyota process
Oakland J.S. 1999	Business Structure and CI Methodology	General framework for business improvement, based upon basic lean concepts
Kobayashi I. 1994	Twenty Keys to Workplace Improvement	Systems development, from the establishment of 5'S to introduction of TBM
Suri R. 1998	Quick Response Manufacturing	Time Based Manufacturing systems introduction
Masaaki I. 1997	Gemba Kaizen	Gemba Kaizen = Workplace and management improvement process based upon basic Time Based Management practices
Shimbun N.K. 1990	Kaizen Team Working	Development of the Kaizen teamwork improvement process to reduce labour content and improve efficiency
Harrington J. 1991	Business Process Improvement	Basics of business process re-engineering and insight to TQ introduction
Ohno T. 1978	Toyota Production System	Full review of Toyota manufacturing systems with the evolution from post 1945

2.7 The Development of the Six Sigma Movement

The Six Sigma process structures C.I. actions and improvements around a statistical framework, progressing through the phases of Measurement, Analysis, Improvement and Control (MAIC). Organisations such as General Electric also include the pre-project phase known as Define to Deliver (DMAIC) (Henderson and Evans 2000). The one thing that S.S. converts agree upon is its bottom-line impact, with corporate America having had little time for anyone who doubts the words of the S.S. messiahs (Welch 1999, Archibald 2002). The very nature of the statistical tools of S.S. indicates that it is a technique of the engineering and management areas. Klefsjo and Edgeman (2001) assert that the novelty offered by S.S. is the marriage of tactical and strategic initiatives to deliver results. Harry and Schroeder (2000) define S.S. as "The most powerful breakthrough management tool ever devised, promising increased market share, cost reductions and dramatic improvements in bottom-line profitability for companies of any size. The darling of Wall Street, it has become the new mantra of Fortune 500 boardrooms around the world because it works".

Harry and Schroeder have a financial interest in the expansion of S.S.: as founding fathers of the movement, they are responsible for much of its development over the last fifteen years. They were fundamental to the development of the initiative in Motorola, from its inception in the mid-1980s to the message-spreading of the 1990s. The program we know as S.S. with its MAIC and 12-step process, has been primarily developed by Harry and Schroeder. "Six Sigma Academy", the consultancy they founded, turned over $100 million in corporate training programs as early in the development of the initiative as 1998. The S.S. framework aims to deliver a set of simple project guidelines, to be used by both practitioners and management

champions (Breyfogle 1999) alike. The twelve steps of the process acting as tollgates, with the project resting until the required evidence of success is provided to the site champion or the manager responsible for auditing the project. All projects are subject to audit and approval at each step or at the end of each phase (Harry and Schroeder 2000), and projects will not be allowed to progress from one phase to another unless sign-off is completed. The twelve-step process (Table 2.7.1) can be considered as highly procedural, providing a simple action plan that can be displayed graphically to register the progress of a number of projects. The guidelines highlighted in the table are taken from the basic project review and auditing rules of the core case study.

	Measure	**Guideline**
1.	Select Critical To Quality (CTQ) characteristic	What area should I be working on?
2.	Define performance standards	What am I measuring? What is the defect?
3.	Validate the measurement system	Do I trust my data? Have I proven GR&R? (Repeatability and Reproducibility measure)
	Analyse	
4.	Establish product capability	How bad or good are we currently?
5.	Define performance standards	How good do I / my customer want me to be?
6.	Identify variation sources	What is causing the problem?
	Improve	
7.	Screen potential causes	Which factors really will improve the situation?
8.	Discover the variable relationships	What are the best settings for all my factors?
9.	Establish operating tolerances	What must I do to ensure six sigma performance?
	Control	
10.	Validate measurement system	Do I trust the performance factor measurement?
11.	Determine process capability	How well am I able to control my factors?
12.	Implement process capability	Ensure improvements are sustained

Table 2.7.1 Case Study A - MAIC Summary Process

Bendell (2003) emphasises that S.S. needs to be planned and deployed in the context of an organisation's history and culture, with a full understanding of its current needs and constraints. It is not a one-size-fits-all panacea. A number of authors have

commented that the Six Sigma initiative should not be seen as an extension of T.Q.M. and the following table highlights a number of differences. The table (2.7.2) has been developed from the Six Sigma to T.Q.M. comparisons of Snee and Hoerl (2003), Breyfogle (1999), Harry and Schroeder (2000), Qi (1997) Banuelas and Jiju (2002)..

Areas Of Focus & Comparison	TQM Perspective	Six Sigma Perspective
Customer Focus	Attempted to deliver a customer focused improvement – often considered as based on soft measures	Attempts to focus on the customer via measurement of key indicators of customer satisfaction. Often linked and focused on the findings of Cost of Failure
Manufacturing Process View of Work	Uses some of the simple mapping tools to review process variation	Highly focused towards a process methodology of improvement with significant use of the tools throughout the improvement process
Continuous Improvement Mindset	Could lack direction in delivering tangible, budgeted results	Links CI to Cost of failure to drive financial improvement
Holistic Improvement Tool	May not be focused on the financially most significant issue	SS has holistic potential if driven appropriately through the business – benefiting from design for SS and transactional training to gain company wide impact
Data Based Decisions	Data often supported the decisions of management	All decisions based upon data at all times and at all levels of the business
Statistical Tool Usage	Some degree of basic statistical analysis is evident, though the technique is not as statistically strong	Very focused towards usage of statistical methods to study and measure variation at all stages of the project
Senior Management Support	Often led by middle managers	Commitment of top level management with a support structure then placed alongside the leadership
Full Time Resources	Often staffed by part time staff in most cases, with the leaders also retaining departmental duties	Lead by full time staff in all significant rollouts
Provides Well Defined Roles In the Implementation Process	Roles may well not be well defined in some TQM initiatives	Clearly understood roles and responsibilities are essential in the rollout process
Financial Impact	Often not focused at the highest levels of financial impact	Focused on financial delivery from the commencement of the program with all projects linked to some degree of financial improvement

Comparisons of Six Sigma and TQM - Table 2.7.2

Snee and Hoerl (2003) argue that many areas of the Lean tools are applicable and helpful to the S.S. drive and they advise understanding both tool sets and using them appropriately. They identify two key limitations of the lean methodology:-

1. The lean tools are not significantly statistical (excluding SPC) and are poor at dealing with process variation and at driving process improvement activity.
2. The tools, in the main, are manufacturing orientated and as such struggle to impact the rest of the business, losing a degree of impact if used outside of the manufacturing environment.

Snee and Hoerl (2003) comment that, "while they consider themselves as certainly proponents of Lean, they also believe that Six Sigma provides a richer infrastructure and toolset for problems with unknown solutions. The critical question, however, is not whether to use Lean or Six Sigma exclusively, but rather how to take advantage of both approaches depending on the nature of the problem".

2.8 Six Sigma – The Management Program

Six Sigma found popularity in the USA through the 1990s and its potential spread globally, the attraction of this program for management in the USA is simple to understand. It is a management controlled, bottom line profit booster, proclaimed by the likes of Welch (1998) to be an essential cost control strategy. Its results can be swift and impressive without the need for involvement of the full workforce. The training is structured in several levels, but the baseline training is targeted at the ranks of the professional and engineering staff. This is in contrast to L.P. development, much of which is aimed at shop floor workers and hands-on processes, developing

incremental improvements with easily understood tools. A three-stage S.S. development program is discussed, by Cheek (2000):

1. **Phase One** - is the basic program of Quality Control (Q.C.), implementing many of the established tools and techniques of capability and control process improvement. This can be considered as the traditional approach to improvement and is viewed as a low-risk strategy.
2. **Phase Two** - progresses to S.S. in its implementation form with the combination of analysis and improved measurement techniques combined with Design of Experimentation improvement and greater focus upon control applications. The focus at this stage is on advanced statistical tools alongside powerful analysis packages. The improvement is very much part of the framework and the structured methodology of S.S.
3. **Phase Three** - Design for Six Sigma (D.F.S.S.) to break the Five Sigma wall with front-end statistical techniques being utilised from the drawing board onwards. Progressive forecasting techniques and simulation packages are used alongside the tools of S.S. to develop design robustness.

Riley (2001) focuses upon the benefits of the S.S. process, although he tempers this with the warning that it is not a "magic bullet." He defines four key benefits:

1. S.S. can significantly influence the bottom and top line of the business.
2. The structured process instils a level of discipline in the organisation's decision-making process, especially around the area of policy deployment.
3. It achieves increased differentiation between the business and its competitors.
4. It increases the organisation's ability to be sustainable over time, through the development of a common language and a solid understanding of what is truly important to the business.

The ability to positively influence the bottom and top line has been confirmed by a number of major corporations such as American Express (Shklar 2000), GE (Welch 1999, 2000 2001) and Motorola (Lavigne 1996, Zinkgraf 2000, Harry and Schroeder 2000), with the added benefit of a significant degree of additional structure being added to the executive decision making and deployment process. Both Riley (2001) and Puuar (2001) agree upon the need for top-down commitment and involvement from senior managers, a view that is supported by Shklar (2000), who highlights the difficulties of launching the process if the appropriate level of management support is not available. This simplistic view does not consider the organisation's structure or the type of management structure that is currently in place, rather asking simply for management commitment to support the initiative. This can be considered as a "given" in any C.I. program and should form the foundation of the improvement initiative. Banuelas and Jiju (2002) expand on this point and attempt to define a number of additional success factors to the "given" of management commitment. They conclude that the management and the organisation must also develop:

1. **A Formal Communication Plan** – to communicate the need for change and commence the elimination of resistance to the program, preparing the ground for the initiative and clearly outlining the process rollout activity and the step by step process the initiative roll out will follow.
2. **A Distinct Organisation Infrastructure** - to cope with the program development and rollout activity and to resolve any ambiguity in leadership.
3. **A Focused Training Program** - to add the "how" to the "why" of the communication plan, highlighting the step-by-step rollout of the skills and knowledge transfer process.

4. **A Clear Linkage to the Business Strategy** - focusing the program on the goals of the business to deliver impact upon the financial and operational goals and ensure that the Six Sigma team focuses upon the needs of the business.
5. **Linkage to the Customer** - with activity commencing and ending with the customer needs, the focus of the program must be the customer's Critical To Quality (C.T.Q.) requirements.
6. **Links Between the Initiative and the Supplier** - rolling out the process to the first and second tier supply base and developing an increased level of capability and partnership. In the second phase of training, improvement activity should be focused towards supplier capability improvement, to ensure that this area progresses, and as such, that suppliers are able to contribute to the total business improvement.
7. **An Understanding of the Tools and Techniques** – taking time to master the individual techniques and the project management skill required to use them efficiently. A full understanding of the toolbox must be developed to ensure that the appropriate tools are used as and when to resolve the pressing business critical issue in hand.
8. **A Project Selection and Prioritisation Process** - to define the project's priority and the attack plan for rollout and ongoing project activity, ensuring that high impact, high value projects are attacked in the first phases of the project rollout. The initial project deck delivering a number of quick wins upon high visibility projects.

While Banuelas and Jiju (2002) have highlighted a number of essential factors for the introduction of S.S. the author would add that the key success factors noted are to some degree universal success factors for the introduction of any new initiative.

2.9 From Motorola to America's Tool of Choice

The birth of S.S. within the Motorola Corporation was in direct response to poor levels of quality performance and significant external threats (Shah 2000), as a result of which the situation looked bleak for the corporation in the 1980s. Motorola had identified a weakness in quality as far back as 1979, although it did not introduce S.S. to the full corporation until 1987, in direct response to competitive benchmarking in 1986, which revealed that Motorola was lagging behind the field by some distance. By 1988, Motorola had won the prestigious Baldrige National Quality Award under the guise of an extension activity to a quality focused company wide Total Quality Management program.

The classic introduction approach subsequently adopted by a number of other American corporations is the strategy employed by General Electric and not the evolutionary early years at Motorola. CEO Jack Welch (1999) advising at his annual management summit in 1999 that GE were introducing S.S. and making it clear that no-one in the room would be able to slow the introduction. Welch backed this up with a memo to all senior managers to announce that promotions would only be considered after they had successfully completed training and managed a couple of significant projects. In the notoriously aggressive GE business, Welch (1996, 2000, 2001) considered this the ideal implementation tactic; this public commitment to S.S. is

typical of Welch and also of GE's style. A number of other implementation strategies by businesses like American Express have had typically low-key CEO support (Shklar 2000), possibly reflecting management culture in the organisation, but potentially jeopardising the long-term implementation effort. Loughlin (2000) and Bader (2000) highlight the need to support S.S. from the boardroom and also to integrate it into the corporate strategy of the organisation.

Hampden-Turner and Trompenaars (2001) and Steve Crom (2000) go one step on from tuning the approach to business culture and counsel individual management and implementation approaches suited to different European countries and cultures. Crom (2000) comments "Beware of blindly adopting approaches that are based on an American style, and be wary of putting emphasis on the capability of talented well-trained individuals to get results no matter what it takes" This again warns of the danger of trying to enforce the terminology and structure of S.S. in European companies without consideration of the implications of acceptance.

Steve Crom (2000), speaking at one of the first European SS conferences, focuses on the combination of organisational culture and unique national cultures in Europe. Crom stresses the need to blend an introductory approach for each combination in multinational organisations that is designed to fit with the national culture of the individual locations. The terminology of S.S. has a distinctly Americanised feel about it (Crom 2000), with martial arts connotations. This does not always fit in with the previous quality and improvement programs of the adopting organisations. As Harry (2000) states, "Polaroid refers to its Black Belts as 'Variability Reduction Leaders' or VRLs; it feels the term flows logically from past quality-control efforts. The phrase

'Black Belt' seems to require a definition within the organisation, whereas the phrase "Variability Reduction Leaders' is immediately understood."

A number of publications define a simple blue-print process for S.S. introduction (Snee and Hoerl 2003, Breyfogle 1999, Harry and Schroeder 2000), although Pyzdeck (1999) and Gitlow and Levine (2005) consider the introduction program as a case of following a basic template, with an appropriate level of tuning. Pyzdek (1999) highlights the difficulty of introducing S.S. in the complex organisations he calls "spontaneous enterprises", citing Visa as one such organization. The lack of hierarchy would require amendment of the S.S. process and a significant modification of the roles of S.S. to enable it to work in such a spontaneous organisation. The Master Black Belts in this organisation could possibly work directly for a business leader and provide information to maintain a competitive edge. Pyzdek (1999a) believes significant analysis of the organisational hierarchy is required to develop an understanding of the best fit S.S. introduction model and unless the initial approach is carefully considered and implemented the business may well reject the process.

A summary of the significant Six Sigma tools and processes is presented in Table 2.9.1 with a focus on the Author, the six sigma tool or process and the area of the business the individual tool could deliver improvement.

Table 2.9.1 Six Sigma Tools and Processes

Author	Tools / Process	Area of Analysis
Anderson & Whitcomb 2000	Design Of Experiments – DOE	Development of the DOE process from simple sampling plans to the more complex design structures
Bhote and Bhote 2000	Design Of Experiments – DOE	Development of a DOE mentality and its links to other statistical techniques
DeVor, Chang and Sutherland 1992	Statistical Quality Tools	Statistical techniques and methods, with a focus upon design and process improvement in manufacturing
Box, Hunter and Hunter 1978	Statistics for Experimentation	Advanced statistical usage in DOE experimentation
Douglas Downing & Jeffrey Clark 1997	Statistics for Business	Basic statistical techniques for use in general business with a broad spectrum of statistical techniques being represented
Jacobs, Walsh and Reid 1995	Measurement system analysis	The concept of measurement system analysis and control with regard to techniques like GR&R studies
Doty, 1989	Reliability Engineering	Handbook of reliability engineering techniques, including the Weibull process and test-to-failure methodology
Snee and Hoel 2003	Leading Six Sigma	Leadership Text Book with a basic step-by-step guide introduction plan
Kececioglu 1991	Reliability Engineering	Hand book of first principle reliability engineering techniques, Weibull process and test-to-failure methodology
Locks (2002)	Weibull Distribution	How to Estimate the Parameters of a Weibull Distribution from incomplete data
Enrick N1985	Process Improvement	Quality and Reliability linked to the process improvement cycle
Thompson 1999	Reliability Improvement	The improvement of maintainability and reliability through the design process
Twine and Sailsbury 1996	Process Variation	The management of process variation as a guide to process management
Morton 2001	Initiative Fatigue	Tools and Techniques to avoid initiative fatigue in the introduction phase of Six Sigma
Picard 2002	Six Sigma Techniques	Guide to the basic techniques of SS including various tables and standard charts
Gravetter and Wallnau. 1999	Statistical usage in Behavioural Sciences	The use of statistics in the study of behavioural sciences, focusing on the interpretation of trends etc.
Dean and Smith 2000	Combining Lean and Sigma	The development of the Lean Sigma process with an appreciation of the interface in tools and techniques
Breyfogle F.1999	Six Sigma Implementation	Implementation process of statistical management tools and techniques
Gitlow and Levine 2005	Six Sigma Skills	Tool book of Basic Skills in Terms of Six Sigma rollout processes
Harry & Schroeder 2000	The Six Sigma Introduction Process	The basics of the Six Sigma introduction process with focus upon management's part in the introduction

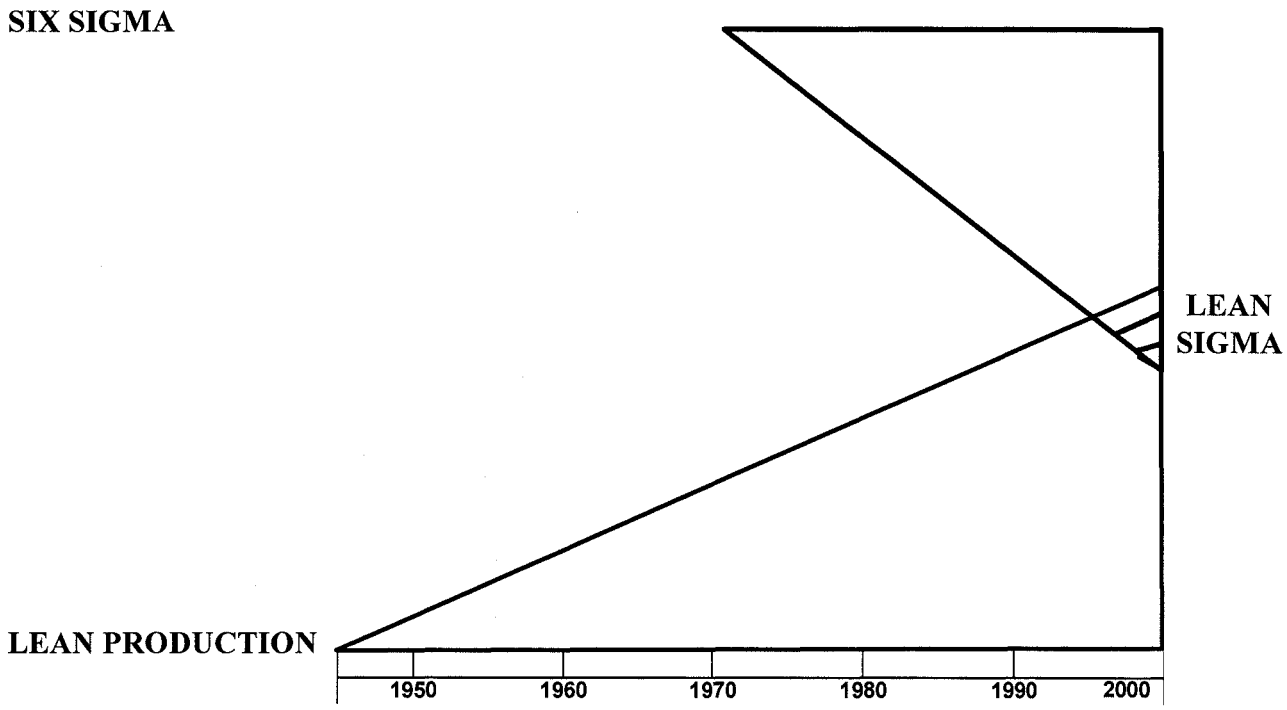
2.10 The Synthesis of Lean and Six Sigma

Measurements affect management behaviour, and Breyfogle (2002) notes that 2002 witnessed a number of corporate American giants paying the price for the creation of an environment that did not accurately reflect true performance. Organisations such as Worldcom stand as testament to the essential need for accurate measurement and reporting (Tilly 2002). Worldcom fundamentally, did know the issues impacting its business and did not question or resolve them.

Harry (2002) focuses heavily upon the aspects of statistical management; he disregards the Lean Production techniques that have developed over the last 50 years and refuses to acknowledge the compromise approach. The development of the Lean Sigma philosophy over the last five years aims to deliver this compromise, integrating S.S. and L.P. approaches in a complementary process. Dougherty (2000) and Dean and Smith (2001) highlight the benefit of combining tools and methodologies to deliver operational improvement, resulting in superior returns to those achieved independently. Figure 2.10.1 highlights the life spans of the individual techniques.

Sharma (2001) considers that the Lean Sigma multi-disciplined methodology aims to provide the full set of tools founded in both approaches and a structured, tried and tested breakthrough methodology for achieving a world-class level of performance. Improvement may well be possible in condensed time-scales, with significant benefits over the traditional L.P. program.

Fig. 2.10.1 DEVELOPMENT OF LEAN SIGMA

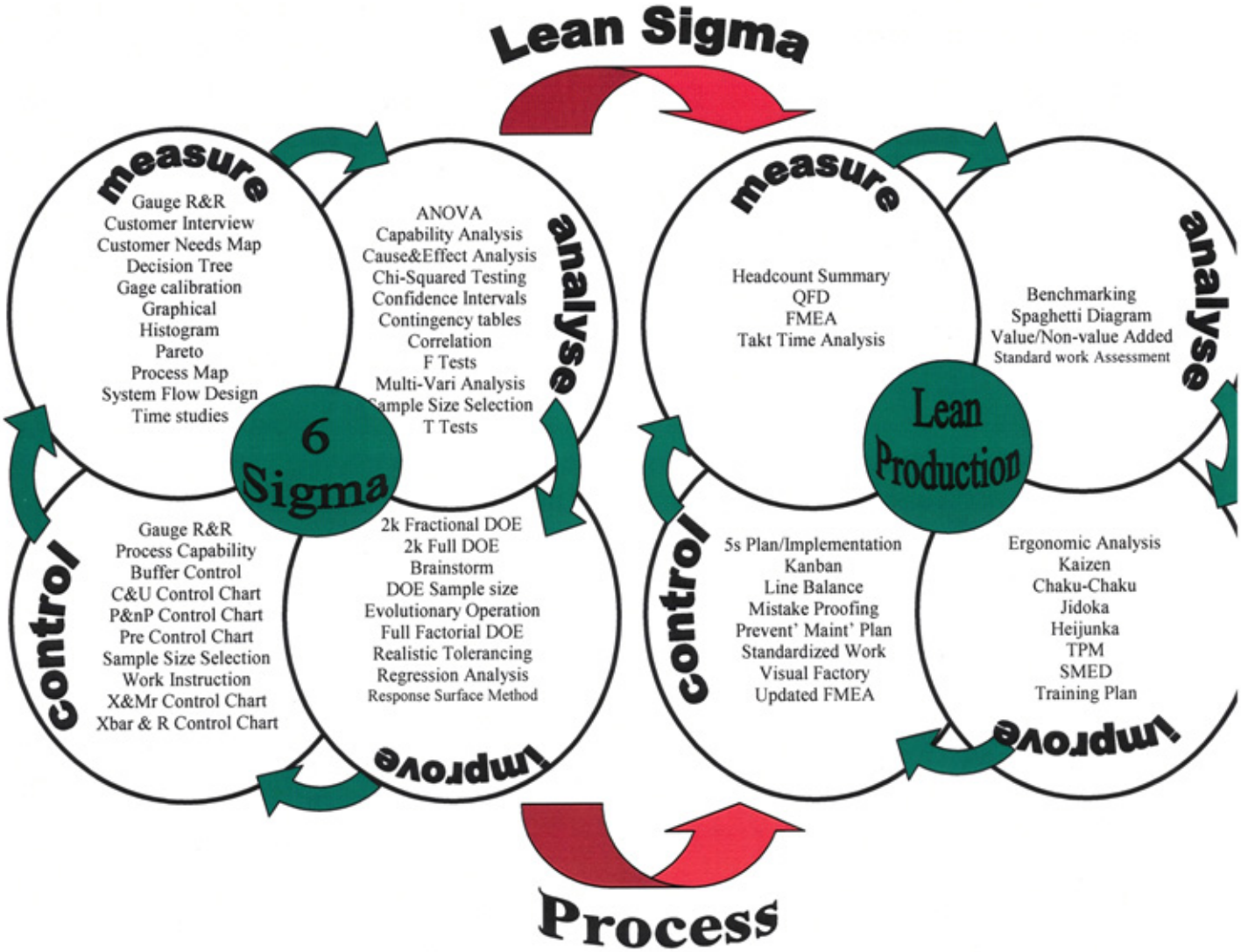


As an early commentator on the blending together of individual techniques, Joiner (1994) advocates rapid improvement and learning processes, listening and responding to the voice of the customer via strategic customer-focused Agile initiatives. Much of his work in "Fourth Generation Management" (1994) is based around the key S.S. skills of process variation and control, combining elements of business strategic direction such as an understanding of Dr. Noriaki Kano's model of customer perception and Dr. Genichi Taguchi's Loss function (T.L.F.). This may be contrasted with the hard technique training on tools such as Central Limit Calculation (C.L.C.). The 1994 publication of Joiner's work could be considered as an innovative and early approach to a form of Lean Sigma, which was subsequently built upon in the late 1990s by a number of organisations

Smith and Beal (2001) emphasise that the Lean approach brings a set of proven tools to reduce cycle times, inventories, set-up times, equipment downtime, scrap, rework, and other wastes of the "hidden factory", developing a new set of metrics based on uptime. The focus is on value from a customer perspective, flowing through the entire supply chain. Few Lean initiatives have the solid framework of S.S. or the management introduction methodology. Sharma (2001) argues that the statistically based problem-solving process of S.S. delivers excellent management data to drive solutions to business priorities, focusing on the key business issues and delivering dramatic bottom-line results. The value-creating potential is acknowledged by a long line of key global industrial leaders, including Welch (1999, 2000, 2001), and has the attraction of a "*how to*" template that is simple to understand and implement. This template has proved to be very attractive to many business leaders who are searching for a quick fix with a proven background of success. The L.S. school advocates a fundamental blending of the two techniques to deliver a full toolbox comprising the common-sense approach of L.P. with the statistical base of S.S. This approach allows a wider involvement than in pure S.S. programs and also delivers a blend of techniques seeking to select the correct tool for the task in hand from the two toolboxes. Pyzdek (1999) suggests that the two approaches should be viewed as complementary to one another. The measurement phase provides time to review the applicable tools that are best suited to the completion of the task in hand, with significant crossover being evident on many projects. One of the best-known global L.P. consultancies, TBM Ltd, is currently refocusing its efforts from L.P. towards Lean Sigma (Sharma 2001), and is indeed proclaiming this as a trade mark. TBM Ltd. was a significant pioneer of the "Breakthrough Kaizen" approach and launched L.P. in a number of UK organisations, including Unipart and Black and Decker. Figure

2.10.2; (Caine and Prabhu, 2001) highlights the common fit of tools through the phases of the SS project.

The Lean Sigma Cycle - Fig. 2.10.2



Dougherty (2000) highlights S.S. as a subset of the Lean approach at Invensys Intelligent Automation, supporting the L.P. strategy in statistical and quality terms, while through the course of 2002, Nissan Sunderland added S.S. through it's 'Value Up' initiative to its traditional Lean heritage. This is viewed as a logical extension to the heritage of L.P. within Nissan. The same scenario is in play at Unipart in the UK,

with additional S.S. training being completed by key L.P. implementation managers. Kenyon (2001) highlights BAE Systems' synthesis of the two processes, with significant emphasis on "takt-time" analysis with the construction of L.P. cells and multi-skilled workers, whilst running with the tools and techniques of S.S. Johnson (2000) highlights Noranda as an example of S.S. being targeted to deliver a performance culture, profitable growth and preferred partner status, linking into the initiatives of key customers. The senior executives studied the improvement models of GE, Allied Signal, Dupont and Bombardier, amongst others, and defined S.S. as the path they wished to follow.

Harry (2000) reflects the interest in pushing S.S. as the improvement tool of choice and does not reflect the findings of a number of organisations that are actually implementing the approach. This indicates the commercial nature of many of the commentators and the constant search for the unique selling propositions in the field of business consultancy. Harry has a significant financial interest in the growth of S.S. through his association with the Six Sigma academy and numerous books and publications on the subject. The work of Pyzdeck (2000c) highlights the management focus of S.S. tools and techniques and the level of sophistication of many of the improvement processes, which work in tandem with the more operator-based L.P. activities. Each initiative fills gaps left vacant by the other, "buying in" the entire business to the L.S. strategy. The combination of L.S. and the technological developments of BTO "E-Manufacturing" will drive efficiency improvements in the next phase of the migration, with world-class companies employing a full C.I. toolkit to drive them forward. Sleeper (2000) highlights the lack of continuous improvements in the S.S. methodology and advises against the view of a fixed toolbox for all

problems. In contrast Harry (2000) voices distinct thoughts on the application of L.P. tools and uses quotes from companies like Bombardier to drive his point home.

> "Kaizen refers to gradual, unending improvement, doing little things better, and continually reaching for higher standards. It is Bombardier's belief that at a certain point the gain from basic Kaizen tools diminishes and the impact of S.S. takes off. Organizations that are between 3 and 3.5 sigma will see that some of their projects look like Kaizen efforts, since Kaizen uses fairly basic tools. But once the S.S. methodology starts using tools such as Design of Experiment, companies make quantum leaps in performance not possible through Kaizen-type efforts. The gains from S.S. projects will be far greater than what can be achieved through Kaizen, particularly when companies begin to change the design of the products they make."

McCallion (2003b) highlights that some businesses feel that S.S. is only for quality, whilst Lean will work on cost reduction. Pyzdek (2000e) has constructed a table (2.10.3) to identify his view of the synergies of S.S. and L.P. The Lean approach offers a set of solutions to *muda* in a high-variety production environment. S.S. applies to the problems addressed by Lean but also seeks to solve other problems common to production. However, because both Six Sigma and Lean address the problem of *muda*, there is a great deal of overlap. The approaches should be viewed as complementary to one another. Pyzdek also notes the benefit of SS alongside L.P. in the total business context, breaking away from a pure manufacturing purge on waste

using L.P. tools. He feels that SS brings distinct benefits in the indirect areas of commercial and logistical operations.

Table 2.10.3 - Synergies of Six Sigma and Lean Production –Pyzdek (2000)

Lean Production	Six Sigma Contribution
Establishes a methodology for Continuous Improvement	Policy deployment methodology
Focus on customer value stream	Customer requirements measurement / cross functional management
Uses a project-based implementation	Brings significant project management skills and tools
Understand current conditions	Knowledge Discovery
Collect product and production data	Data collection
Document current layout and flow	Process mapping and flowcharting
Time the process	Data collection tools and techniques SPC
Calculate process capability and takt time	Data collection tools and techniques SPC
Create standard work combination sheets	Process control planning
Evaluate the options	Cause and effect, FMEA
Plan new layouts	Team Skills, project management
Test to confirm improvement	Statistical methods used for valid comparisons of processes of improvements
Reduce cycle times, product defects, changeover time, equipment failures	Seven management tools, seven quality control tools, design of experiments

The predictable and precise methodology of Six Sigma, combined with the speed of Lean Production, can provide a statistically proven solution in the search for increased efficiency. The elimination of waste or "*muda*" and improved process capability is a common goal of both L.P. and S.S. and with the integration of the tools and the twelve steps of Six Sigma we fill a gap missing in some L.P. programmes.

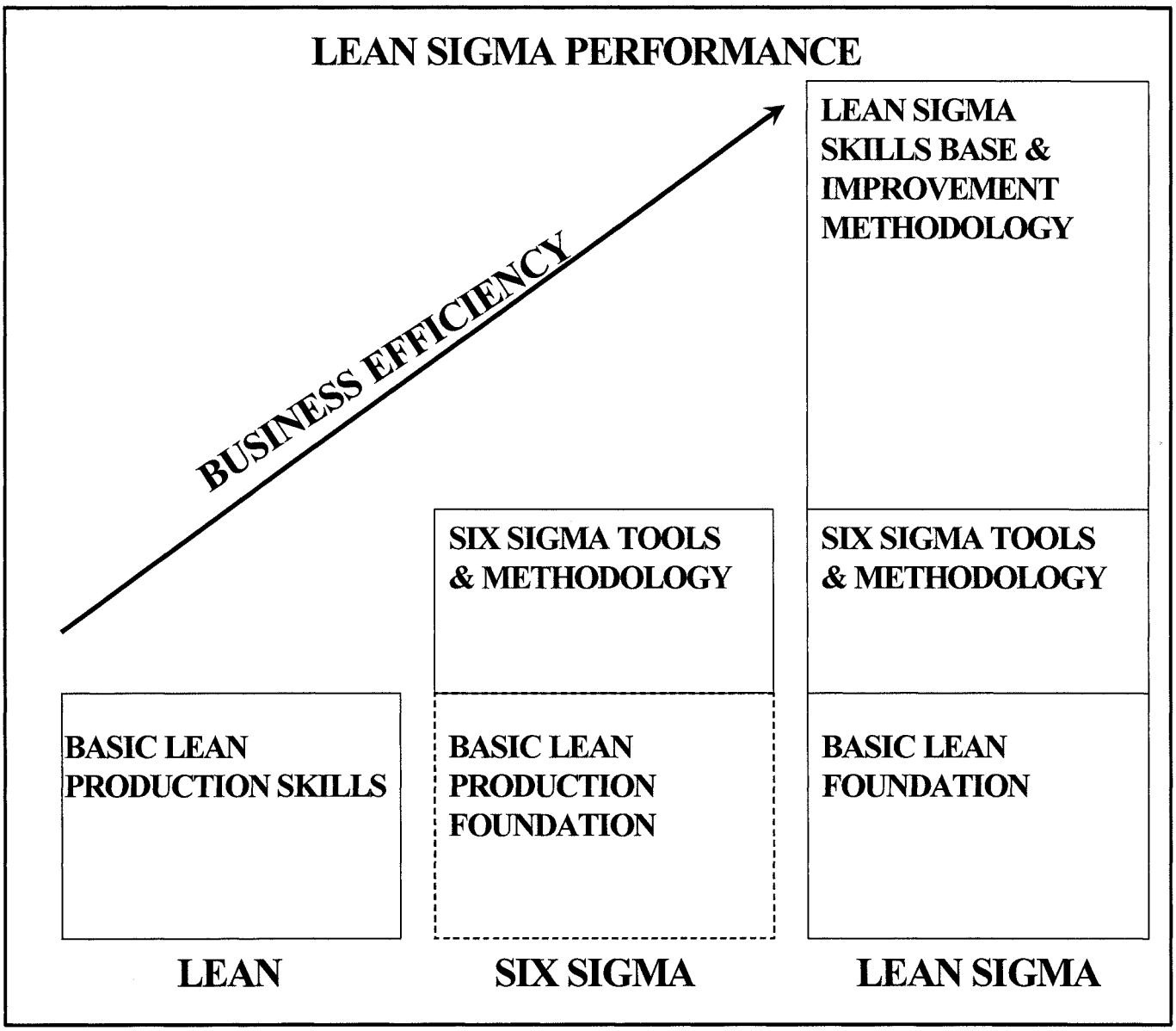


Fig. 2.10.4

Significantly adding to the robustness of the program and having a dramatic impact on the time scales of change. The benefits of the synthesis of L.P. and S.S. may outstrip the individual impacts of either initiative, as represented graphically on Fig. 2.10.4

The combination of S.S. and L.P. with Cost of Failure (CoF) assessment activity or Cost of Quality assessment, as highlighted by Bowman (1994, 1997), increases the company wide focus and the responsiveness and capability of the entire value chain. Aggressive identification and elimination of non-value added activities (waste), alongside the company-wide measurement process provided by CoF, allows

improvement in the flow of value through the organisation. The addition of the structured waste identification process helps with project identification and benefit tracking as well as establishing a financial thread through the annual objective setting process. In line with the thoughts of Sharma (2001) and George (2002), the blending of the Lean skill base and the S.S. improvement methodology may deliver improved business efficiency.

Dwyer (2003a) completed a TBM Ltd. Lean Sigma awareness course and was astounded by the benefits generated in the manufacturing simulation process, although he also highlighted the fact that the "new" materials and processes that were preached were at least twenty years old, and some were much older. Jones (2003) feels that the willingness to deploy the techniques is in place, but that there is still a shortfall of people who can really lead firms beyond the basics. Basu (2004) calls the approach of blending Lean Sigma and the Agile school of thought "Fit Sigma" and he feels it is the logical next step from the Lean Sigma technique. He reflects upon the need for the progressive building of solid foundations of the initiative and a migration process that works in three distinct incremental waves:

1. **The First Wave - Moving from the current state of 'AS IS' to Total Quality Management (T.Q.M.) -** developing the basic foundations of C.I. with the mastering of the simple tools of waste assessment and process mapping and improvement skills, the activity being founded on a management awareness of a strategic need to change the status quo and develop a new customer focused approach to running the business.
2. **The Second Wave - The progress from Total Quality Management (T.Q.M.) to Lean Sigma Business -** commencing the development of the

time based manufacturing techniques, and customer order beat focus that takes the customer orientated T.Q.M. business towards a Lean, efficient, statistically driven manufacturing business founded upon the synthesis of the Toyota Manufacturing System with a growing understanding of the tools and techniques of Six Sigma.

3. **The Third and Final Wave – The Leap from a Lean Sigma company to a Fit Sigma business** - the state of balance achieved with the combination of Lean Sigma tools and techniques and manufacturing practices and the Agile customer orientation of a number of progressive technology manufacturers such as Dell. The Fit Sigma facility benefiting from the manufacturing focus of Lean Sigma and the planning technology and software systems evolving from the Build To Order (BTO) facilities.

2.11 E-Manufacturing To Order (E-MTO)

Michael Dell, in his quest to take his organisation to new levels, understands well the attraction of having customers' hard cash deposited into his bank account prior to commencing the building of a personal computer for them. In its simplest form, this relationship delivers a customised PC to delight the consumer, fulfilling all the CTQ's whilst significantly smoothing the cash flow of Dell. They don't start to make your computer until you have paid for it. Dell, then, lives or dies on the condensed delivery lead-time and accuracy of the Make To Order (M.T.O.) system. The concept of M.T.O. is not a new one; Alvin Toffler discussed the "lot size of one" from the early 1990s and espoused the need to roll out the principle from manufacturing into all aspects of life. The concept of moving mass customisation towards demassification

(Schwarz 1993, Toffler 1998) draws upon media and communication to highlight companies like ABC and NBC as delivering a single message to millions of viewers and listeners. The new digital and satellite age delivers hundreds of tailored messages and interactive formats to the consumer.

Welch (2001) presented his vision of e-business to General Electric's annual general shareowners' meeting in the form of a three-phase plan:

1. **Commence with "e.Sales" at GE,**
2. **Progress "e.Buy"**
3. **Finally break into "e.Make."**

Welch aligned the development of the e.Sales aspect to the development of the Amazons of the world and highlighted the $20 billion dollars of GE goods and services sold on-line in 2001. On the buy side, he predicted that GE would procure $12 billion of goods in global auctions and save over $600 million in doing so, in line with the developing dot.com revolution. By Welch's (2001) own admission, however, the big breakthrough is in e.Make and the combination of S.S. with digital technology. GE projected that 2001 / 2 would see a billion dollars of cost removal from the e.Make initiative and the advances to the manufacturing systems. GE was named by both Internet and Worth magazine as the e.Business of 2001. On the compatibility of S.S. and e.Business, Welch (2000) comments, "S.S. fits like a glove with e.Business because it allows us to produce and deliver just what customers need when they want it. S.S. quality defines the ultimate in customer fulfilment and satisfaction: just what e.Business requires." The American consultancy Papilio (2000) defines L.S. in the following way:

> "Six Sigma is the pursuit of ACCURACY (make everything right first time), whereas Lean is the pursuit of SPEED (make everything as fast as you can). The ability to bring these two together into a powerful marriage provides enormous leverage to any business. In isolation they are useful, whereas together they will take your business to the new levels of sustained competitiveness"

The definitions - "fast" and "accurate" - ignore a number of alternative schools of thought, such as the Agile approach and M.T.O. / Mass Customisation. The concept of building to the specific requirements of your customer, having already taken payment for the product prior to procurement of the component elements, is attractive to all manufacturing companies. This concept has been pioneered in the computer industry by Dell and brings together L.P. and S.S. alongside advanced and sophisticated inventory management and logistics systems (Serwer 1998, Kirkpatrick 2001). According to Kanellos, et al (2001),

> "The greatest problem HP and Compaq face is Dell's manufacturing strategy. Through its M.T.O. manufacturing capability, Dell has managed to cut many of the risks of the PC business. The company can survive on lower inventories and take advantage of price cuts more quickly than competitors. Selling PCs directly to customers also cuts costs by eliminating dealer mark up."

The B.T.O. phenomenon includes balancing manufacturing and marketing. Ody (2001) quotes Dick Hunter, Dell's VP of manufacturing in the USA: "We don't know

what will be ordered each day so we have to design a flexible operation that can move production up or down as need be. B.T.O. involves balancing what is available with what the customers want and Dell has become expert in gently massaging both factors. Any shortage in a particular component is immediately countered by offering other available products on promotion." He defines the key factors of B.T.O. as:

1. **Flexible Manufacturing Facilities**
2. **Integrated Supply Chain Capability**
3. **Speed**

Hunter combines two cutting-edge tools used at Dell (Perman 2001), "event tracking", a minute-to-minute computerised vigil of the transportation process, and "demand shaping" using detailed feedback to entice customers to cover up for shortages in other products. O'Hanlon (2003) quotes Michael Dell's claim that component parts are manufactured on average only eight hours prior to leaving as finished PCs. This is possible through Dell's route to the market and the successful blending of a model of L.P. S.S. and B.T.O. that fits the PC market very well. The next expansion into servers and storage equipment may strain the manufacturing and sales model of Dell. Roth (1999), Morris (2000) and Gibbs (2001) question the M.T.O. model as Dell grows into its range expansion plan. Dell meanwhile continues to mould the initiatives together and generate ever-lower inventory levels and quicker response times. Rocks (2000) highlights the Austin Texas plant performing with two-hour inventory levels and PCs being loaded onto trucks 15 hours after the customer has clicked on the "buy" button (Deck 2000). The changes have increased manufacturing throughput by 150% and line uptime by more than 95%. The "plug and play" concept of Dell's modular system is under review by many automakers (Andrews 2000), with organisations across the world learning from the Dell model. Tony Abbott, MD at

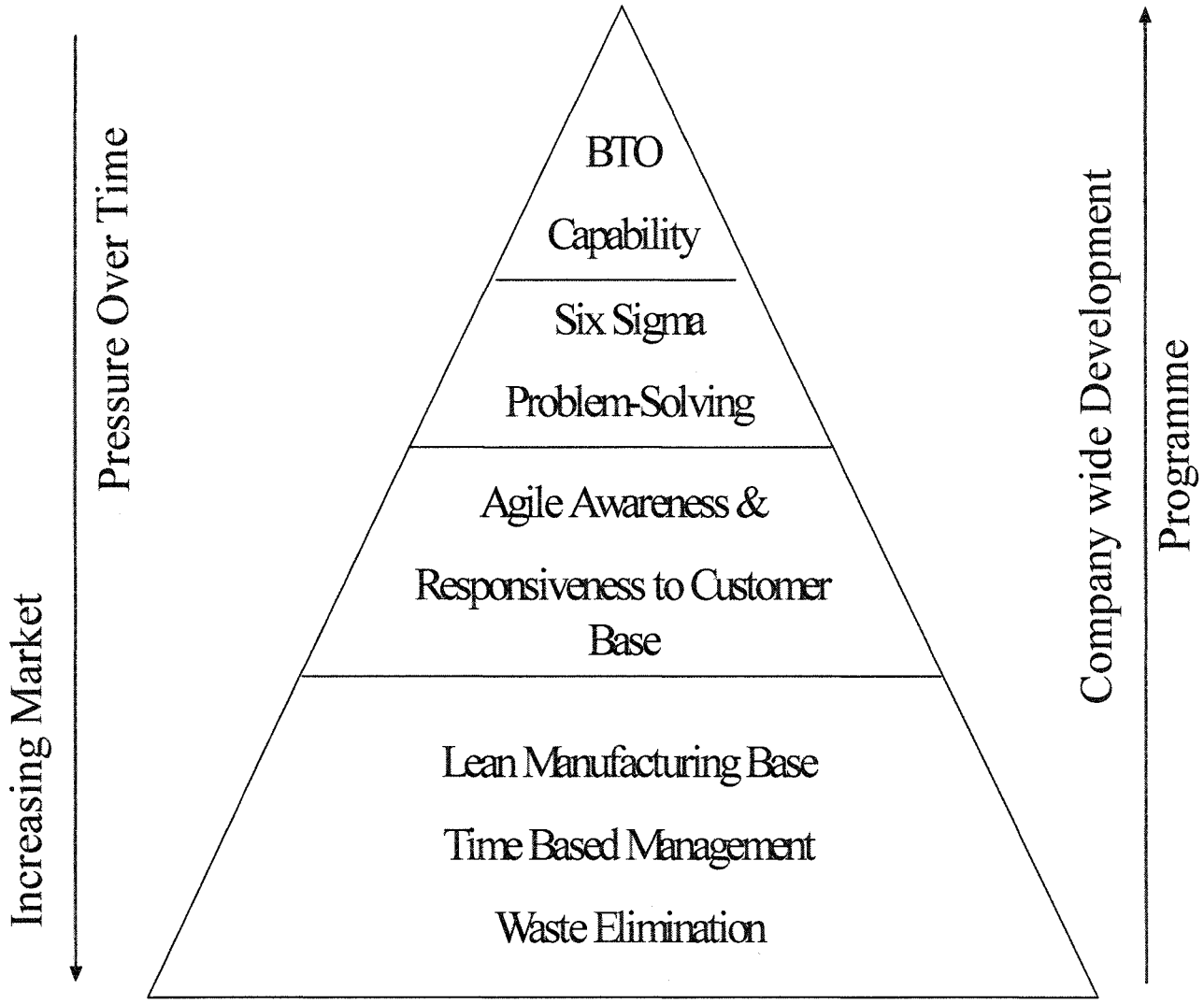
Sanyo Manufacturing UK (O'Hanlon 2003a), recognises the need to manufacture in real time in line with the principles of Dell, although he highlights the difficulties of the pull system when dealing through retailers and distribution chains. In 1999, Sony UK started to manufacture every TV in the range every day.

Toyota is actively working on supply chain flexibility with web-based developments (Songini 2000). This is the element that Dell call "pull-to-order", an essential aspect of M.T.O. Dell practice a number of techniques side by side and openly discuss S.S. projects (Breyfogle 1999) such as D.O.E. (Bhote and Bhote 2001), development and reliability Weibull modelling (Kececioglu 1991), tools we might expect from a technology company. Yurko (2001), in his paper on E-Manufacturing, summarizes the performances to be expected from the manufacturing organisations of the future (Table 2.11.1). He draws comparisons with the classic MRPII plants, Lean Sigma plants and e.manufacturing plants of the future. The performance of the e.manufacturing plants involves "stretch" targets, with the exception of inventory turns of 20 x per year. This is a level that is currently being achieved by a number of Lean businesses and surpassed by many Lean organisations in the automotive and FMCG sector (Womack and Jones 1990, 1996).

Table 2.11.1 -The Combination of Six Sigma, Lean Enterprise and E-Manufacturing – Yurko 2001

	Average plants – Classic MRP II Manufacturing	Best plants – Lean Enterprise & Six Sigma	Future plants "E-Manufacturing"
Lead Times	3 months	3 Days	12 – 24 hours
Quality Level (Defects)	500 PPM	50 PPM	3 PPM
Inventory Turns	5 x / year	10 x / year	20 x / year
Delivery Performance	90%	98%	99.9%
Sales Growth	3%	8%	10%+
Return On Sales (%)	10%	16%	20%+

Fig 2.11.2 - LEAN SIGMA DEVELOPMENT PYRAMID



Hendry (1998) contrasts significant elements of the appeal of world-class manufacturing with the reality that many B.T.O. organisations produce goods in relatively low volumes with significant variety and little or no common components. Much of the literature is based upon make-to-stock manufacturing or mass customisers, and as such it does not have full applicability to the B.T.O. sector. Panacucci (2004) comments that many important issues require consideration prior to assuming that "real-time" manufacturing is good or even necessary for a business, considering the extra investment in structure and technology to support the move.

Karlson (2002) argues that any form of mass customisation requires a modular product design and assembly concept at the core of the business model, with significant drawbacks for any business attempting B.T.O. without the modular design and assembly approach. The Lean Sigma case study facilities recognising the attraction of the build to order capability and whilst all of the facilities had established the development base of the pyramid highlighted in Fig. 2.11.2 little substantial progress towards modular design had been established in the case study facilities. The migration activity in the above figure reflects the establishment of a Lean Manufacturing base, tuned to the need to perform with an Agile focus as the first steps towards the adoption of the problem solving skills and management structure of the S.S. process. The pinnacle of the development pyramid is the synthesis of the various approaches and the establishment of a B.T.O. modular process encompassing the skills and techniques mastered through the migration process.

2.12 Business Migration and the Management of Change

The perils of the introduction of change have long been understood; in 513 BC, the Greek philosopher Heraclitus observed, "There is nothing permanent except change" and this remains true today. A number of authors have suggested change models (Oakland 1999) based on the incremental development of our current systems and processes. A counter-argument is made for radical reform of the core business strategy (Moore 2000) with the call for a new model embracing the reality of the new electronic age. Considered management of this change process is essential as we drive improvement programs through manufacturing organisations; initiatives will live or die on the management of the introduction process. Do we manage the change process

internally or through a consultant, with the known perils and pitfalls of outside intervention? This is a question that Magil (1996) would like us to consider prior to commencing change. Magil (1996) asks us to identify whether we have symptoms of initiative fatigue or insufficient management support, and whether we have a picture of the organisation as it currently stands (Morgan 1986) and a vision of the new "religion" (Watt 2002). The author is of the opinion that all of the above questions require significant management consideration and strategic review prior to commencing upon the journey towards change.

Kotter (1995, 1996) has developed a preliminary three-part framework, based partly on the 1940s work of Kurt Lewin: He advises the organisation to consider the following outline steps:

1. **Defrost the Status Quo**
2. **Take Action that Brings About Change.**
3. **Anchor the Changes in the Corporate Culture.**

The Kotter framework requires significant development to fit into the transformation methodologies outlined by the author, who feels that the additional developments offered by Rose (2002) and Coutts (2000) assist in compensating for the structural weakness of the basic framework. Both authors advocate the Kotter process and advise a structured approach, progressing through a series of eight steps, commenting that skipping steps create the illusion of speed, but rarely ends in a satisfactory result. The change management methodology fits well with the L.S. school of thought and could help to establish a roadmap for introduction, based on a series of milestone steps, as represented in chart 2.12.1. The author has attempted to tune the change process to an L.S. introduction activity.

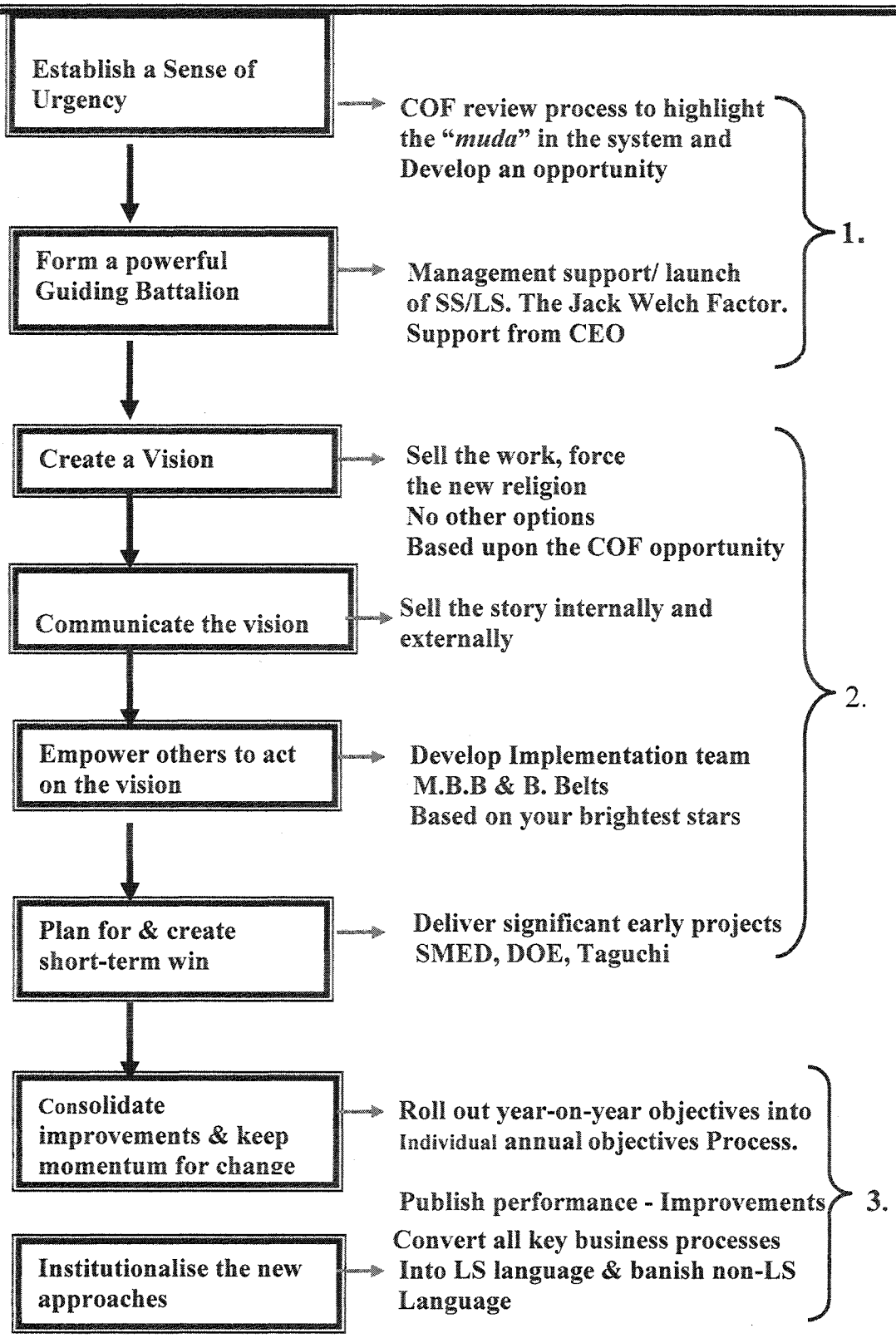
A number of authors have discussed the fundamentals of the S.S. / L.S. introduction process, with two distinct schools of thought coming to the fore. Zinkgraf (2000), Townsend (2002), Lavigne (1996) and Rushwin (1996) are very much in tune with the Kotter, Rose and Coutts school of thought and advocate the structured, holistic process. In this approach, progress towards company-wide acceptance is made through a series of tiered training and rollout steps. The time-scale of a significant launch program may well involve several years of training and deployment prior to the first project-based returns being reported.

The contrasting blitz approach of Adams (2001), Patton (1997) and Sheridan (1997) has immediate appeal and promises quick wins with cultural transformation workshops leading the organisation along the road to change. The synthesis of the two processes could well increase the rate of progress of the introduction activity, delivering the initial financial benefits from the blitz training weeks and highlighting a successful change project in a known area of problems, also helping to prepare the employees of the organisation for the more structured rollout that is to follow from the initial quick win scenario.

Figure 2.12.1 highlights the use of the Kotter change process in a Lean Sigma roll out activity.

Figure 2.12.2 reflects a simple flow chart of the link process of Lean and S.S. used in the core case study facility.

Fig. 2.12.1 - The Kotter Change Model In a Lean Sigma Business



Initiative Introduction Process

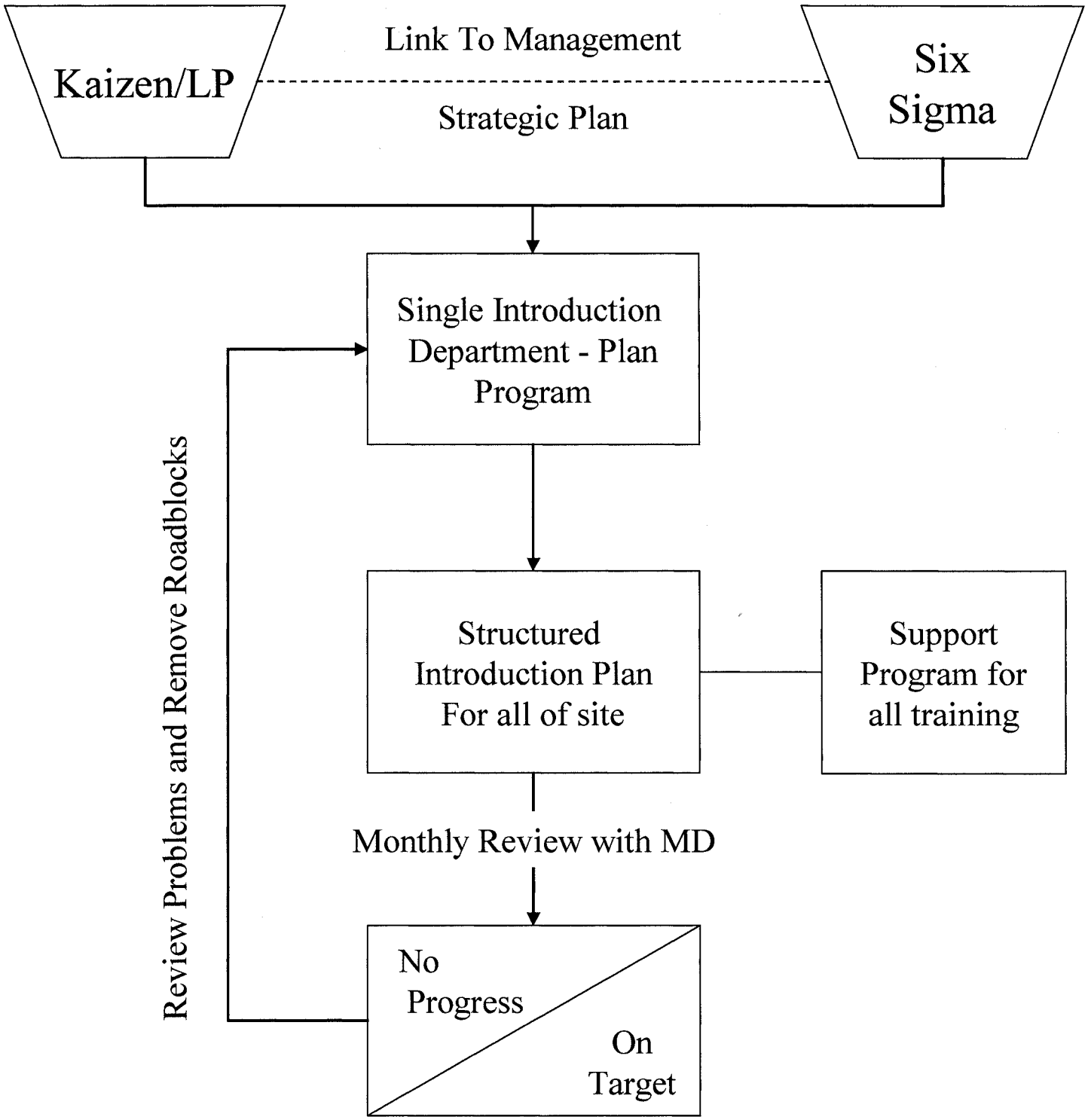


Fig. 2.12.2 Initiative Introduction Process

2.13 Summary of the Literature Review

Delbridge and Lowe (1998), Gabrys (2003), Hill (2000) and Kumar and Somani (2002) highlight the massive transition in manufacturing that is currently sweeping through the western industrial world with many C. I. initiatives finding favour. Dove (1997) believes that the effort to try and differentiate "mass customisation or Lean from Agile miscasts all as operating strategies. Asking for the differences between T.Q.M. and Agile misplaces both as transformation strategies". Agility in itself is a fundamental requirement in manufacturing organisations. Pfeifer et al (1994) also agree that individual strategies cannot be considered in isolation: "it is not enough to introduce only one of them into a company".

Cooney (2002) argues that both the batch and craft approaches are still applicable to certain elements of the luxury automotive and specialty component sectors and that industry should not ignore their benefits for certain manufacturing tasks. Cooney (2002) argues that industry is blinkered by following the latest trends in assembly technology or product development, and that the constant quest for "flow" blinds many organisations to the potential benefits of a combination of craft techniques and lean skills. Cooney's (2002) conclusion highlights the thought that "Lean is not a system with universal applicability and it provides only a partial model for manufacturing systems." He advocates a comprehensive review of the problems and the task we face and calls on organisations to review the process that best fits the products that they produce and the volumes and customer pressure they are placed under. His thoughts are supported by James-Moore and Gibbons (1997), who highlight a number of areas in the manufacture of "super high value goods"

(aerospace and power generation) that recognised the demands of Lean Production, but have found that only 60% of them are applicable to the aerospace or power generation industry. In the field of business operations, Klefsjo, Wiklund and Edgeman (2001) do not see S.S. as a company-wide alternative to T.Q.M. and argue that T.Q.M. is more about management values and company-wide culture than the tools and techniques offered by the dollar delivery process of S.S. They view S.S. as a development of one part of the T.Q.M. methodology. The case study organisations considered in this research program can be considered as having T. Q. roots reaching various degrees of development in the methodologies of T.Q.M. commencing the development of the methodology in the 1980s and early 1990s, and subsequently progressing towards the more efficiency-focused initiatives of subsequent C.I. initiatives

The economics moulded by the pace of global change have influenced and shaped management strategies and C. I. activity, and this process is evident throughout the literature review. Harry (2000) and Breyfogle (1999, 2002) highlight the need to company wide measurement systems as a key element of the C.I. activity helping to supply a measurement yardstick for the strategies of today's internal competition (Hill 2000) in response to the global threat from the Far East and Eastern Europe (Caine and Prabhu 2000, 2001). The development of an internal strategic review process and a customer-focused attitude (Moore 2000) combined with a clear view of the competitive threat have accelerated a number of development and learning curves.

Chapter 3. The Research Methodology

"Most of the research conducted in the field of operations management is based on statistical survey analysis and mathematical modelling. However, embracing a field investigation technique such as case studies is bound to make the individual researcher, and the field in general, better prepared to solve real, OM problems" - McCutcheon and Meridith, 1993

The researcher faces several challenges in case study analysis in the field of operations management and significant rigor is required to ensure that valid results are produced at the end of the research process. Voss et al (2002) comment that despite its drawbacks, case research can have a significant impact, and that, unconstrained by the rigid limits of questionnaires and models, it can have creative insight, "playing a significant part in the development of new theory and having high validity with practitioners." The research activity conducted by the author covers a significant longitudinal study over a period of change for manufacturing in the UK, with the author participating as an action researcher at the core case study facility whilst in parallel taking a positivist stance in the study of three satellite case study organisations. The review of the satellite studies being conducted via structured interviews and regular interaction with the key change agents at each facility.

The research activity was embarked upon with the aim of objectively recording the evolution and development of the facilities C.I. activity, documenting the salient drivers and attempting to recognise the limiting factors at play in the change process. The extended and open nature of the study has enabled good access to many previously untouched aspects of the case study facilities and helped develop a number of key relationships. The ability to develop a creative insight, without the restrictions of a rigid questionnaire or fixed model, has been highly beneficial, allowing the

development of an open relationship with the case study businesses reflecting the findings and observations of the study. The longitudinal study followed a number of key steps:

- **The initial literature review in the fields of T.Q.M. Lean Production, Agile Manufacturing and Six Sigma methodology** – the initial activity can be considered as a literature review process focused upon exposing the latest research in the C.I. and manufacturing operations management field and then striving to put the knowledge into context.
- **The development of a basic research question** – the research commenced with a consideration of the fundamental research question that the longitudinal activity would aim to consider and through the course of the process answer, through the detailed case study assessment and the cross case analysis with the satellite studies.
- **Selection of a number of case study organisations** – fundamental to the integrity of the study is the selection of robust case study facilities and the establishment of solid links to key respondents and change agents.
- **Development of a research protocol applicable to testing the research question** – the research protocol developed and utilised in each case study can be considered as an essential element in the development of an academically sound research project and all effort has been made by the researcher to ensure the protocol has been followed upon each site visit.
- **Field research conducted in each of the case study organisations** – fair and unbiased field research designed to follow the research protocol and consider all aspects of the case study facilities development, founded on the current status but also looking to consider historical aspects and future direction.

- **Data collection, documentation and comparison of results and perceived performance improvements at the key case studies** – the nature of longitudinal case studies in operations management expose both fact and anecdote in equal measure with the author aiming to test the anecdotal evidence while collecting empirical evidence.

The drawbacks of case study research and interviewer bias are well recognised, and as such the research process attempts to use elements of triangulation in each case study comparison, with multiple means of data collection being considered for all key data sets. The emerging nature of the subject area has introduced its own problems over time, and significant emphasis has been placed upon the research protocol to ensure that the appropriate level of academic discipline is adhered to.

3.1 The Research Question

The fundamental premise of the research activity surrounds the belief that the historical tools and methodologies of Continuous Improvement have been radically improved by the two distinct methodologies of Lean Production and Six Sigma. Both techniques having created a step change in performance for the converts of the two schools of thought, delivering significant and measurable improvement in many areas. The C.I. initiatives of Lean Production and Six Sigma when combined may ultimately deliver improved benefit, with the logic of the natural complementary approach over time becoming readily evident to practitioners of both techniques. The research question is based on the following hypotheses:

H1 - The Introduction of Lean Production Techniques will lead to reduced waste and delivery of increased production efficiencies.

H2 - The Introduction of the Six Sigma Initiative will lead to the delivery of significant financial impact through project delivery.

H3 - The Synthesis of the two Techniques into Lean Sigma will lead to the delivery of the best elements of both initiatives, complementing the business toolbox, reducing waste and delivering significant financial bottom line impact.

The research commenced in the early stages of the study with the development of an interview structure, highlighted in table 4.31.1, 4.31.2, 4.31.3 and 4.31.4, designed to ensure that an impartial approach was taken through the course of the study period and all areas were reviewed in each of the case studies. Attempts have been made to minimise or eliminate the possibility of interviewer bias in the study process and the simple interview matrix was designed to focus the author's attention, to ensure coverage of all areas in each of the studies. The initial structure was developed in conjunction with a number of colleagues and fellow researchers, brainstorming the logical areas for review in a business evolution and Continuous Improvement (C.I.) process. At each step, every effort has been made to follow the line of sound case study theory and the practical guidelines advised by Yin (1994), with progressive development through the course of the study. Consideration has been given to Yin's (1994) case study tactics for design tests, focusing on the construction of the case study, the internal and external validity and most importantly the reliability of the study and its findings. The author has aimed to allow for multiple-case replication from a holistic review perspective, whilst not allowing the research activity to become restrictive in the field analysis stage.

The research has attempted to review and question the development of each case study and answer both "How & Why" (Yin 1994) aspects applying the findings from these developments to both theory development and theory testing in the later stages of the studies. The research has attempted to maintain a standard approach to the key study and the satellite case studies by ensuring focus on the following four key areas:

1. **The Initial Focus upon the Individual Company Profiles** – commencing with the definition of the culture of the study site in comparison to the prevailing corporate culture and the level of message consistency viewed by the researcher. Aiming to identifying any pertinent industry drivers and reviewing with the case studies a competitor sophistication analysis.
2. **Consideration of the Case Studies Evolutionary Process** – comparing the current business direction stimulus with the historical C.I. Strategies rolled out by the case studies and measured against the time scales of the evolution. The progress being monitored alongside any champions and process leaders identified through the migration period.
3. **The Assessment of the Individual Case Studies Path Analysis** – reviewing any common shared industrial themes and the development models followed by each case study, inclusive of any industrial partners and any benchmarking activities that they have undertaken and recorded findings upon.
4. **Any Identifiable Development Templates Followed** – considering any consolidated, holistic models followed or elements of parcelling techniques already undertaken by the case studies, combined with a view on the proposed next steps for the businesses as a corporate entity and an individual site.

The research question postulated the synergies of the Lean and Six Sigma movement and predicted significant gains from the marriage of the two techniques, the researcher also aimed to understand the migration paths taken by the case study organisations in the journey from TQM towards the current business model of choice, Lean Sigma, in the case of four case studies, asking both causal and non-causal questions, highlighting the development and definitions of the continuous improvement initiatives witnessed in each of the studies. The research also aims to search for causal relationships between the initiatives and the perceived performance improvement of the case study sites over the full period of the study. Voss et al (2002) identified the development over time of research questions in case study analysis and emphasised the strength gained in allowing for knowledge development and generating theory tests on the foundations of theory building. The study was commenced with a view to exploring the following areas:

1. **Had the deployment of a T.Q.M. initiative prepared a solid C.I. foundation for each of the case studies.**
2. **The general acceptance of the need for a next development step on from the T.Q.M. program was apparent in each of the case study companies.**
3. **The case study businesses were contemplating the development of various levels of the Lean Production.**
4. **Within the development of Lean techniques, the case study businesses had a pressing need to retain the appropriate level of Agility, recognising the level of flexibility demanded by the industry they participated in.**
5. **The development of Six Sigma tools and techniques and the C.I. management structure associated with the Six Sigma methodology fitted well with the C.I. process and system across each of the case studies.**

6. **The development of the holistic technique of Lean Sigma would become the eventual C.I. process of choice in each of the studies as they grew to appreciate the synergies of the two techniques.**

3.2 Selection of Case Studies

The case study selection activity aimed to expose the background of change and the forces that were reshaping European business, the activity commenced early in the research process, allowing the author a period of time to consider the current level of C.I. sophistication of the facilities and to develop an understanding of the current improvement technique status of the case study businesses. The case selection process ran alongside the original literature review and the development of the research question and hypothesis. During the course of this project, the parallel activity of the hypothesis development and testing, literature review and the initial case study activity has aided significantly in guiding the author towards a clearer understanding of the C.I. needs and the sequential activity of the initiative introduction process.

The research has attempted to balance access to respondents and to focus upon the possibility of performing a longitudinal analysis, additionally focusing upon cause and effect and the sequential nature of the events studied. The very nature of the longitudinal study and the mobility of change agents have restricted the ability to track a key respondent through the course of the study. It can be concluded that the reliance upon key respondents through similar longitudinal study periods cannot and should not be relied upon as a cornerstone of research. The research aimed to

complete interviews with personnel at several levels of the case studies throughout the study period, and as such, gained a degree of stability from the junior management interviewees and shop floor operators that aided the quest for continuity through the study period. The approach of targeting several levels in the facility aims to deliver a more holistic degree of feedback on current or historical issues with a broad spectrum of feedback being sought in each facility. Three satellite case studies were selected, with histories of continuous improvement activity and a reputation as leaders in the industrial sectors in which they participated. It is noteworthy that in terms of the longitudinal study conducted, the economic and market influences have played a significant role in the evolution and development of each of the studies and any conclusions drawn from the study requires consideration of these factors alongside the significant internal and external changes witnessed in each of the case studies.

3.3 Development of a Research Protocol

The prime information source for much of this hard research has been the use of formal interviews with personnel at various levels in the management hierarchy of the case studies. This activity has been supported by personal observations and general informal conversations whilst on the shop floor of the case study companies. Yin (1994) highlights the need to develop a relevant protocol for case study investigation, and the research process has attempted to follow a general funnel model, developing from a general base of foundation questions and progressing to a more specific investigation into the use of the tools and techniques. One weakness identified in this process can be summarised as follows, while all personnel in the business are willing and able to comment on the history and culture of the business and a significant

number are able to discuss and comment on its current strategy and activity, only a small number of the entire staff can discuss the next C.I. steps and the proposed strategy of continuous change. The very nature of the next level of change could possibly call into question long-term manufacturing site strategies and employee commitment, and as such, information on the "next steps" was found be very difficult to get to grips with.

The research has attempted to address the aspect of triangulation within the protocol, as advised by McCutcheon and Meredith (1993) for multiple case study research. The author concurs with the findings of Leonard-Barton (1990) and feels that the longitudinal nature of the study and the developing nature of the subject area have allowed many of the critical developments to be observed at first hand. The evolution witnessed through the course of the study would have been difficult to capture by any other study methodology, and the first-hand nature of the information capture has allowed the researcher to balance the relative merits of many of the advancements witnessed and consider critically the introduction strategy for C.I. throughout the key case study and the satellite supporting studies.

3.4 The Field Research Conducted

To better understand the change process alive in the case study facilities attempts were made to obtain access to the key informants as early as possible in each of the studies, viewing the identification of the prime respondents as critical to establishing a true understanding of the case development. Identifying the mutual benefits and advising on elements that the author could bring to the table were essential to the

development of this credibility link (Voss et al 2002) or to ensuring the continuity of the study. The most significant issue encountered throughout the study could be defined as the transient nature of the "change agents", with significant managerial changes being witnessed in each of the studies through the course of the longitudinal study period. The loss of the prime respondents has been an issue in each of the studies, with continual change occurring throughout the six-year period. The author has attempted throughout the research period to gain access to the key change agents across the companies and maintain this contact through the full duration of the study period and as such appreciates the turnover of individuals with high levels of capability in the ever lucrative area of business change and C.I. activity.

The onsite process practiced throughout the research aimed to establish the prime respondent as a key contact on the first extended scene setting and assessment visit with regular contact ongoing from this point forward, alongside the gaining of access to the management change agents driving the migration and setting the strategic direction of the business. The structure of the process can be summarised as follows:

- **Initial Site Assessment – between 1 and 5 working days** - the initial site visit and first contact with the management team aimed to capture a view of the business in its current level of C.I. sophistication. The key respondent has been identified at the earliest opportunity of this initial assessment.
- **Onsite Update – between 6 and 18 month intervals** - through the course of the study regular onsite updates have been conducted by the author the visit being either time phased or triggered by a C.I. development.

- **Regular contact with the prime respondent – between 3 and 6 month intervals** - the research process attempted to maintain regular contact with a series of prime respondents through the course of the study with regular contact and updates on the changes witnessed day to day in the case studies.

3.5 Data Collection, Documentation and Comparison

To capture the change rolling through the case studies, the main thrust of the research has been based upon the use of structured interviews with prime respondents, change agents and parties affected by the change, and as such, the researcher studied the recommendations of Yin (1994) on the skills required to complete such field research interviews. As a single interviewer conducting the interviews, the researcher recognises the pros and cons of the technique of unstructured interviews and has attempted to approach the activity from a neutral base and remain open throughout both the building and testing of his hypotheses. All relevant comparable data has been collected and used to develop triangulation whenever possible. The research has focused significantly upon sequence determination to aid in the understanding of cause and effect, and concurs with Voss et al (2002) that case research has significant advantages over survey research in the observation of change and continuous improvements in manufacturing industries. Efforts have been made throughout the study to understand and limit any of the elements of observer bias in the research process, although the danger of a single interviewer becoming openly in favour of his specialist field of interest is acknowledged. Each of the studies imposed restrictions on tape interviews and in recording some degree of performance data, as a result of which the author has critically reviewed his findings after each session to ensure that

observer bias is kept to a minimum prior to updating the permanent research record. The researcher fully appreciated the need for impartiality throughout the study and has attempted to maintain his neutrality through the course of the entire study period.

3.6 The Relationship of the Research Program and Current Work in the Field

The research has attempted to stay at the forefront of the global research in world-class manufacturing techniques over recent years, maintaining this study activity in line with current "best practice" thinking. The most significant area of focus in the study remains the UK manufacturing segment, reflecting the author's historical experience and his current field of practice. Practical activity has been limited to the UK, although multi-national organisations have been studied, and as such, a global flavour is presented through the case studies. A global context has been gleaned from an understanding of the international corporate goals and initiatives present in each of the case studies and in a number of other businesses visited throughout the study.

Nissan is a good example of this activity; although it is not one of the formal case studies, the author has made several field trips to the Washington site and has conducted discussions with key change agents on a regular basis, with the discussion agenda covering continuous improvement activity and techniques, implementation strategy and introduction tactics. Nissan have attempted to harmonise the statistical management techniques of S.S. with the well-established Lean Production model at Washington over the last two years.

3.7 Project Maturity - Migration from the Original Objectives

The author commenced the project with an understanding of the power of the tools and techniques of the Japanese Lean Production methodology and a practitioners understanding of the benefits and plus points of the emerging school of Six Sigma. One of the key questions he needed to answer considered the compatibility of the two techniques, were they mutually exclusive? The blending of the two techniques at the commencement of the research had little or no public discussion and the two schools of thought could be considered by some to be in conflict. The synthesis approach appeared entirely logical and the author commenced a longitudinal case study and a series of satellite studies to monitor the growth and development of the two individual techniques and record any development of the blended approach we now know as Lean Sigma.

The early stages of the research considered the migration of the case studies, progressing from T.Q.M. management methodologies to Lean Production manufacturing acceptance, with any identified key milestones along the journey being charted to help construct an understanding of the foundations required for the building of a stable and recognisable Lean manufacturing base. The medium of longitudinal case study analysis allowed a detail focus on a key case study and three satellite studies alongside related research material to understand the progression of the study organisations against the drive to remain the "best in class" in the UK.

Through the course of the study, the research has developed and matured in line with the progressive development of world-class manufacturing in UK industry.

Throughout the case study period, the author has had the opportunity to witness the evolution in continuous improvement thinking and the synthesis of a number of initiatives into a unified process we now accept as Lean Sigma. The initial stages of the research project focused upon the study of the progression from the tools and techniques of T.Q.M. through its contribution as a building block of Lean Production in a manufacturing context and the parallel development in the United States of the Six Sigma methodology and its subsequent migration to the UK. The author focused upon the two schools of thought, as "best in class" at the beginning of the study process and the initial analysis is representative of a particular moment in the evolutionary time-scale of this industrial development. Subsequent developments in a number of the case study businesses and in industry in general have extended the project's scope into a holistic view of Lean Sigma in several of the studies.

The initial element now forms the foundation of a comprehensive study project charting the development threads that lead towards the commencement of the Six Sigma initiative and subsequently the growth of the Lean Sigma School in Europe. The author has monitored the development of the initiative in the USA and its acceptance and growth in UK industry, supporting this progress with significant practical experience. The author's participation in a Six Sigma rollout process commenced in the late 1990s and highlighted the benefit of the development of the logical synthesis of Lean Production and Six Sigma, moulding itself into the emerging concept of Lean Sigma.

This synthesis has been reflected independently in each of the four case study organisations by 2005, with other substantial UK reference companies following

similar paths, with terminology changes thinly disguising the subtle development of a Lean Sigma approach. Nissan Sunderland offers a good reflection of this emerging transition towards the use of Lean Sigma as the core CI technique, combining the well-established techniques of Lean Production with Six Sigma in its "Value Up" project. The dual approach to continuous improvement and problem solving is being rigorously adopted in the methodical Nissan fashion. The present study reflects three distinct phases highlighted in each of the case studies:

- **The foundation and development of the roots of a form of management process we know as TQM** – the Total Quality Management initiative has been considered as a starting point in each of the case organisations, with the T.Q.M. initiative helping to prepare both the management and the workforce to accept the principles of future C.I. activity, developing an acceptance of change.
- **The adoption of a second phase initiative in each of the studies** – the second phase can be recognised in all of the studies as a form of time based manufacturing or a form of Lean Production, with the subsequent blending of the initiative with the companies existing T.Q.M. initiative. The two initiatives have commenced as an extension of T.Q.M. in the case studies, prior to developing into a full Lean Production initiative.
- **The development of a third phase through the synthesis of the Lean Production and Six Sigma schools of thought** – the Lean methodology in each of the case studies can be considered to have developed into a clear form of Lean Sigma in the core study and one significant other. Of the two remaining studies one will migrate to L.S. in 2006/7 and the remaining study will continue the S.S. skills development process. In the authors opinion all of the current case studies

and manufacturing elements of the study research activity have commenced some form of synthesis of the skills of Lean and Six Sigma.

3.8 The Case Study Process

The use of a core case and satellite studies has allowed the findings to be compared and contrasted through cross case analysis and timescales to be compared case by case as the individual studies tackled the competitive threats and technology developments applicable to four differing industries. The power of case studies in times of technological change and rapid development in managerial practices is highlighted by Voss, Tsikriktsis and Frohlich (2002) and the researcher fully concurs with Voss et al, and believes that the process of longitudinal case study research has captured the essential elements of the change in the research process and ensured that the author, has been able to witness the evolution in the context of the normal business process operation. This removes the need to retrospectively analyse possible drivers and the relative weight of the change factors within the study, replacing this retrospective element with first-hand analysis. The longitudinal nature of the case study analysis has allowed significant time to be spent monitoring progress and change in four distinctly different organisations, with each case study developing at its own pace and reflecting differing market responses and defence strategies. Throughout the process, the researcher has visited and studied a number of other world-class organisations and developed an extensive literature review, covering a wide range of the many aspects of manufacturing Continuous Improvement techniques and methodologies in a number of differing guises. The synthesis of the case study analysis technique with an extensive review of the methodologies of manufacturing development resulted in the

construction of a qualitative study conducted in a time of rapid change in the world of manufacturing. The findings reflect the transformation that has been evident in much of industry across the UK over the last six years and the continued war against increasing market competition in all industrial sectors. The case study process in the core facility has been based upon action research with the satellite studies being conducted from a positivist standpoint (Yin 1994), following a generative model through the course of the study process.

All of the case study organisations have commenced the migration from Total Quality roots and various degrees of development in the methodologies of T.Q.M.. Starting to follow various T.Q.M. methodologies in the 1980s and early 1990s, and subsequently commenced a movement towards the more efficiency-focused initiatives of Lean Production, Six Sigma and latterly Lean Sigma. At the research commencement none of the case studies would have recognised the methodology we now know as Lean Sigma, though all cases had some basic grounding in the simple C.I. techniques of both schools. None of the case studies can be regarded as reflecting Lean Sigma as a declared strategic initiative at the commencement of the study.

The case study organisations are based around different market sectors and all manufacture a range of products in the UK. The range is diverse, covering products from pharmaceuticals to power tools. The one common element that all the case study companies agree upon is the need to continually improve business efficiency to stay one step in front of the competition, both external and internal. All of the case study organisations have faced increasing levels of competition over the life of the case study process, and this has influenced and shaped the management strategies and

improvement activities in evidence. The author has attempted to document the changing nature of this competition and accurately reflect the defensive strategies adopted by each company. Although each case study is operating in a different market and competitive pressure, all have recognised the need to migrate from the model of T.Q.M. towards Lean Production and ultimately towards a form of Lean Sigma.

A significant area of commonality highlighted in the case study organisations is the development over the last decade of company-wide manufacturing strategies in terms of measurement, improvement and continuous improvement planning processes. All of the case study companies are leaders of the fields in which they compete, and are constantly striving to remain as such, with often ruthless strategies of internal competition alongside the global threat from the Far East and Eastern Europe. The development of an internal strategic review process has accelerated a number of the development and learning curves witnessed in the case studies and brought to the fore a number of key internal decisions. The researcher concurs with the need to consider the strategic direction both globally and locally to ensure that the business is best placed to face the increasing international pressure. The use of the corporate or central C.I. strategy and a local, regionalised delivery and implementation approach is recommended throughout this study.

Economic decisions taken by the case studies primarily reflect the emergence of Far Eastern and Eastern European competition rather than the success or failure of individual improvement techniques. The impact of global economics is sweeping aside many of the financial savings and improvements delivered by UK organisations. It is recognised by the researcher that market forces will at times undermine

individual or local C.I. strategies, and that success or failure cannot be defined without a wider view of the current economic pressure upon industrial sectors or the impact and pressures on the business.

3.9 Assessment and Development Matrix

The case study assessment process is founded upon measurement with a frame of reference focused upon areas of detail that are intrinsically difficult to measure. A simple question and assessment matrix of the case study companies, has been was used throughout the study period to focus on this area. This structure was developed at the outset of the study process and it has remained constant as the case studies developed, the key aims can be considered as follows:

- **To Ensure that a Common Assessment Approach** - can be applied to all case study organisations through the course of the study period, normalising the process of assessment and discussion with individuals within each organisation.
- **To Develop a Simple Frame of Reference** - to aid the understanding of the key industrial drivers at play in the case studies, reflecting both internal and external influences that moved and motivated the development of each organisation as it migrated through the phases of continuous improvement development.
- **To Contrast the Impact of the Complexity and Sophistication of the external influences** - over the study period, reflecting the defensive strategies called into play as a result of changing economics and market forces.
- **To Compare the Drivers, Industry to Industry** – to help in the understanding of the differing time-scales of similar impacting issues across differing industries.

- **To Ensure that all Areas of Assessment and Measurement were Discussed and Fully Exposed** - in each case study organisation, applying a checklist approach to each case study to ensure commonality across all cases.
- **To Develop a Simple Visual Aid** – to enable comparisons to be made across all studies throughout the study period and as an aid to cross case analysis.

The use of the simple matrix has focused the research throughout the longitudinal study period and allowed a continual process of cross-reference from the satellite studies to the key case study. The use of such a framework in longitudinal case study assessment is to be recommended to the operations management researcher, aiding the ability to be concise, structured and complete whilst helping to maintain neutrality.

3.10 The use of Case Studies in Operations Management

It has been asserted that in general, qualitative research in the field of organisational sciences lacks the rigor and discipline of the quantitative approach. Patton and Appelbaum (2003) view case studies as representing an important research track, not only for generating hypotheses for quantitative studies, but also for the generation and testing of theory. Case studies have been defined as the investigation of contemporary phenomena within a real-life context and consisting of multiple sources of evidence (Yin 1989). They may hold a degree of quantitative data, although qualitative data usually predominate (Eisenhardt 1989). The stereotyping of case studies as ill-disciplined and lacking precision is touched on and discussed by a number of authors (Yin 1989, Gummerson 1991, Patton and Appelbaum 1993), and careful consideration

of the structure and rigour of case studies is essential to establish the academic credibility of the research method.

Hamel (1995), in his review of case study methods, notes two possible areas of criticisms in the use of case studies in the field of social science:

1. They lack true representation in the observation of social phenomena, such that generalisations can not be made on the basis of case studies.
2. Poor rigour in the collection, construction and analysis of empirical data can be introduced by bias on the part of the researcher and the informants included in the study.

Hamel (1995) counters both of the arguments and is supported by Patton and Applebaum (2003), with reference to work from Kaplin (1964) to the current day on the danger of academic reasoning driving the principle of "Let's get it down to something we can count!" as the accepted research methodology. The author feels that the statistical closed-system approach does not always accommodate the intricacies of the manufacturing organisation and the complexity of inputs and outputs in large manufacturing environments.

The manufacturing case study embodies the power of the case study process in times of technological change and rapid development in managerial practices; this is highlighted by the work of Voss, Tsikriktsis and Frohlich (2002). The process of longitudinal study captures the essential elements of the change and ensures that the practitioner is able to witness the evolution in the context of the normal operation.

3.11 Case Study Process and the use of the Yin Methodology

Yin (1994) highlights that case study evidence can be obtained from six differing sources, the case study research conducted by the author aims to capture appropriate evidence from each of the six sources:

- **Documents** – collected from the case study sites over the course of the change management process at the core case study and various site visits of the satellite studies.
- **Archival Records** – of historical developments or performances measures collected at the commencement of the case study process.
- **Interviews** – conducted on site with all levels of management, staff and operators, throughout the case study duration.
- **Direct Observation** – of the many processes and procedures evident across the various sites, throughout the regular site visits.
- **Participant Observation** – gleaned from the many workshops, training activities and change management activities performed on the core case study and a number of workshops and training activities performed by the author on the satellite case study facilities.
- **Physical Artefacts** – collected throughout the study period across all sites.

The guidance of Yin (1994) has also been considered by the author in the following areas of the research activity:

- **Consideration of both the How and Why Questions** – the research focuses upon the strategy and tactics of the C.I. change management process and also upon the rational driving the C.I. methodology of the facility.

- **Focus upon Contemporary Events** – the research follows the evolution and development of the C.I. methodology and as such the activity aims to focus on the contemporary activities across each case study facility.
- **Does the Activity Require the Control of Behavioural Events** – the longitudinal study process does not require control of the behavioural events or activity and attempts to follow and record behaviour in its natural state.

The case study process performed by the researcher has aimed to consider the various cases to develop a degree of cross case analysis and to generate primary data for rich theory building and theory testing and has considered each case as an individual experiment, not as the multiple respondents in a survey. Prior to the selection of the case study organisations, the author commenced the early stages of the project with the development of a simple, open and flexible question and review matrix (Table 4.31.1/2/3/4). The design of the review matrix attempted to ensure that an impartial approach was taken through the course of the case study selection process and research period, with efforts being made to ensure that each identified area was available to be reviewed with the change management team in each of the case studies. The researcher has attempted to minimise or eliminate the possibility of interviewer bias in the study process by sticking to the defined areas of the review framework, and by the process of ensuring that each element of the simple framework design was covered at each stage of the study, the author aimed to focus his attention to cover all of the framework areas in each of the case studies. The review matrix allows for cross case analysis, whilst not becoming overly restrictive and thus impede the practical nature of the assessment of continuous improvement. The case study process is constructed from an action based perspective in the core case study and a positivist standpoint (Yin 1994) in the satellite studies and has followed a generative

model through the course of the longitudinal study process. The research can be considered as a combination of action research and general positivism in keeping with a number of other case research studies (Saunders, Lewis and Thornhill 2003), the author has attempted to think flexibly whilst maintaining the required discipline required of a work of this nature (Phillips and Puch 2000).

3.12 The Case Study Selection Process

Considers the evolutionary path of a series of case study facilities, focusing on a core key case study organisation and compares and contrasts that path with a number of satellite case studies. The author has an action-based role in the prime case study and a monitoring position in the satellite case studies. The selection process commenced early in the research, alongside the initial literature review and in each of the studies, attempts were made to balance access to key respondents with the possibility of performing a longitudinal case study analysis, focused upon cause and effect, the drive towards continuous improvement and the sequential nature of the events studied throughout the research period. A number of unrelated case studies were selected, with histories of continuous improvement (C.I.) activity and established reputations as leaders in the industrial sectors they participated in. The core case study facility can be considered as having an excellent history of continuous improvement activity over many years and also a well-established reputation as a leader in the power tool sector. As a long serving member of the site management team, the author has been granted good access to many areas of the business and his relationships at many levels were considered to be vital in the extended open study process. This has allowed the development of a creative insight whilst maintaining an objective view of the

development of the manufacturing site. At the commencement of the study, the author considered the facility fulfilled many of the requirements to complete a longitudinal qualitative assessment. The key criteria for selection of Case Study A can be considered as follows:

- The author has been employed in various change management roles within case study A over the course of the study, and as such the availability of key respondents has been guaranteed, with extensive access.
- The facility has a significant history of continuous improvement initiatives on the site, being one of the prime movers in the UK in the field of T.Q.M. in the 1980s.
- Case study A can be considered as an organisation open to change, with a history of progressive change management for over twenty years on the site and an incremental Continuous Improvement record throughout this period.
- The case study can be considered to be as an industry leading business in the market of power tool manufacture.
- The business has faced challenges and competitive threats, throughout the study period, from both internal and external competition.
- The structure and shape of the business at the facility can be regarded as reflective of much of industry, though dealing in an individual market segment with global supply chains and distribution networks.

The author recognises the dangers of the researcher being fundamentally involved as a key change agent in the case study process, and has attempted to remain impartial and unbiased through the case study period by critically reviewing appropriate development steps with both his academic peers and work colleagues. The satellite studies have been used to provide a degree of triangulation and to ensure that any bias was identified early and eliminated from the study.

4.0 Case Study A

"As Engineers and Mechanics we stand behind our work; we as a company sell service and quality" – Founder of Case Study A. 1910

The key research activity has been conducted at a manufacturing facility in the North of England that has a significant history of change management and has striven to stay ahead of the competition in the power tool industry, through progressive management and manufacturing techniques. They can be considered as UK pioneers in techniques such as Quality Circles and TQM through the 1980s and 1990s, and more recently, innovations such as Six Sigma have taken centre stage in the manufacturing facility. Case A is a leading global manufacturer of power tools in both the consumer and the professional field, and the Northern facility has historically been the most prolific production site in the corporations manufacturing base. The site was regarded as the world's largest power tool manufacturing plant for a number of years in the 1990s: annual production volumes peaked at around 14,500,000 power tools, with peaks of 550,000 power tool units per week in the middle of the garden tool production season.

4.1 The Company Background

Case A manufactures and distributes power tools under two brand names, one for consumer power tools and one for professional power tools both have high consumer recognition in Europe, with internal brand research conducted across Europe reflecting consumers' recognition of quality and value in its product offerings. The professional sector is serviced with a range of tools that currently hold the position of first or second market leaders in all European power tool markets. The industrial power tools brand of case study A competes in all of the major professional categories and can be considered particularly dominant in the field of cordless power tools. The

range holds over 250 distinct tool offerings, from a complete range of cordless tools through to stationary and workshop machinery.

The company has a long history of manufacturing activity in England, and in 1925, a London site was established as the first non-North American site of the rapidly expanding power tool manufacturer. At the end of 2003, the business had global sales of $4.5 billion dollars and 22,300 employees operating in over 100 countries. The UK expansion developed into a manufacturing facility for European production in the 1950s, and the company made an additional significant investment in the world's then largest power tools site in the North of England. The facility was established in the mid-1960s, initially the facility aimed to take advantage of the low labour rates in the North, harnessing the high levels of skilled men who had been made available as a result of the decline in the heavy engineering industries of mining and ship building.

The management objective from the outset was to develop a "world class" manufacturing facility based upon best practice techniques, empowerment and teamwork. This remained the aim of the management team through the lifetime of manufacturing at the facility. The objective of developing "world class" manufacturing in the North has been recognised externally on a number of occasions, and as far back as 1988, Simon Caulkin reported upon case study A (September 1988). One former HR director who worked for case study A between the years of 1990 to 2000, added, "The managers inherited a fabulous legacy from hundreds of previous mangers at the site over the years; it's the duty of the current management team to continue the growth and development of this." The long history of world-class manufacturing practice is still at the forefront of today's management strategy and has

formed the bedrock for the development of subsequent processes and techniques. This initiative continues in the remaining elements of the facility, manufacturing motors and components for other assembly locations, although all assembly of tools ceased at the facility in December 2003. Engineering, Purchasing and the European quality management team remain alongside the motors and component manufacturing facilities. All of the areas are now focused upon support of the other assembly facilities around the Globe. The key internal customers are the new low-cost assembly facility in the Czech Republic, and an ongoing spares requirement for the 100 million plus power tools in operation around Europe.

The Northern facility had historically been considered as the jewel in the crown of the global manufacturing network until the European power tool market deteriorated in the late 1990s and a redundancy and cost reduction program was implemented across the facility in 2002/3. The facility had historically produced in the region of 13,500,000 power tools annually, though the seasonal nature of the business demands peaks of up to 535,000 electric motors per week. The net sales value of the business would peak in the region of $650,000,000 per annum with two distinct seasons:

1. **Pre-Christmas consumer power tool pre-build**
2. **Late winter and spring garden season pre-build**

The business had traditionally been based around high volume consumer power tools and gardening care equipment, for the European market, developing through the 1980s and 1990s to encompass a greater share of the US home market. The launch of the professional brand in Europe established a need for cordless professional tools, with production commencing in the mid-1990s preparing the way for an extensive launch of the professional products in Europe. The case study facility gained

significantly in terms of volume with the closure of a sister European professional power tool plant in Italy in quarter 3 of 1998. This decision resulted in the transfer of a number of industrial tools to the case study facility, including Pneumatic and Percussion Hammer Drills and heavy duty Jigsaws, and Routers. The product transfer process was also supported by substantial investment in component manufacturing equipment and machining process improvement.

Future growth and development of the facility had been predicted to be founded upon professional product expansion, with consumer products migrating towards manufacturing facilities in the PRC (Peoples Republic of China) to take advantage of low cost labour rates and component costs in a market sector driven by product cost. This move would theoretically allow the global power tool business to maximise the technology and experience available at the facility to deliver world-class professional power tools in a market segment that is driven by image, performance, durability and reliability.

In 1999, the General Manager, commented upon the hand-held vacuum cleaner: "We buy the motor, charger and Ni cad cells from the Far East, leaving only the reasons of service level and inventory holding in our favour. This product will go to China to be assembled: the future of the Northern plant is professional power tool manufacture, with an integrated manufacturing facility. We will cut our own gears, wind our own motors and injection mould our own plastic clamshell assemblies." The corporation dramatically changed the manufacturing direction by announcing in 2002 that all assembly would leave the facility and the accessories packing plant would close. This activity would result in the loss of 1500 employees and leave only the design team,

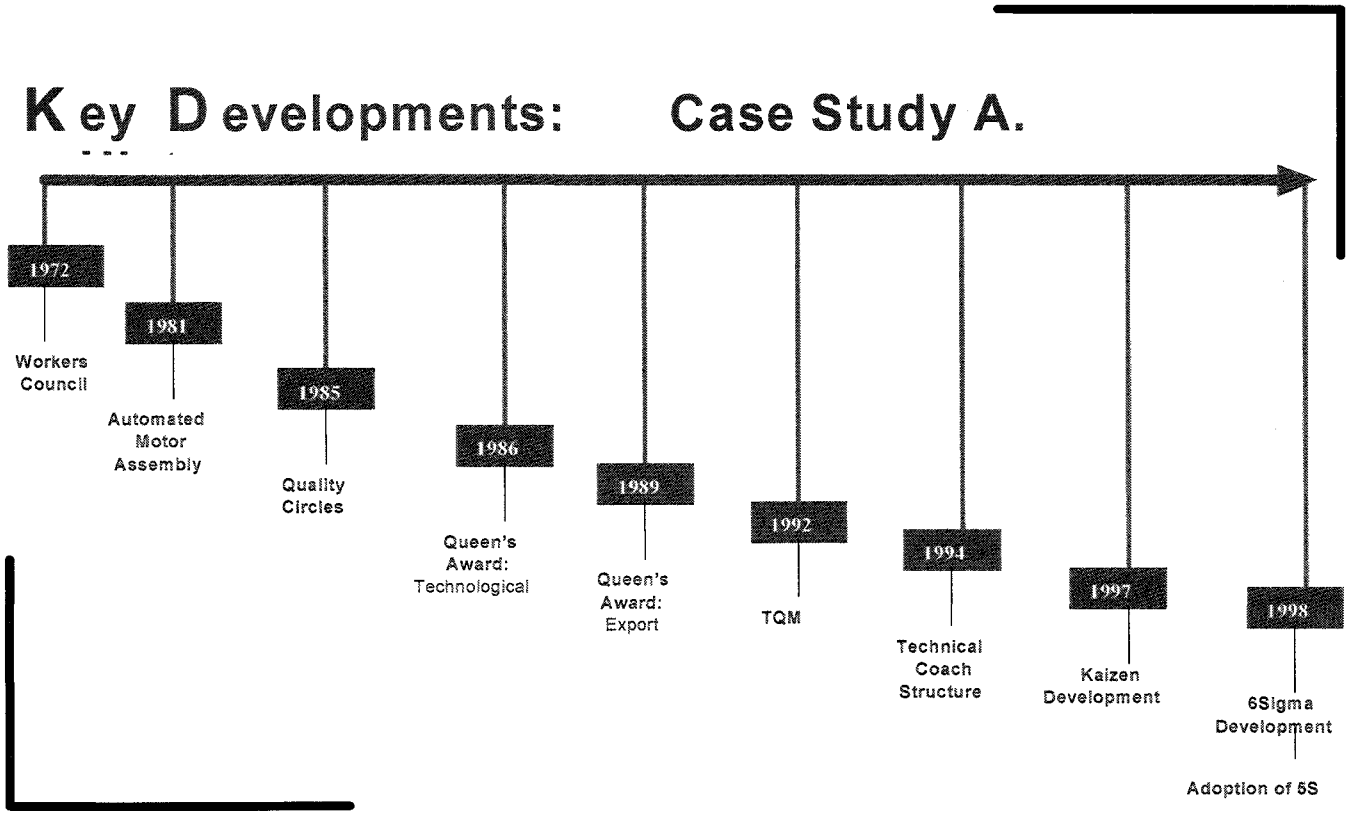
purchasing group, mechanical components and motor manufacturing facilities at the case study facility. The workforce was reduced to 450 employees on site at the case study manufacturing plant, with the significant volume assembly moving to the new Czech republic assembly facility or facilities on Mainland China.

4.2 The Manufacturing Development Process

The engineering centre at the case study employed in the region of 100 design staff, having design authority for a number of key products, and was historically also responsible for product liaison (engineering development after product launch) engineering upon the products manufactured at the facility. The twin facilities of design and manufacture developed together and have been at the core of the success of the plant historically. Innovative design combined with the latest manufacturing techniques equalled "world class" performance for many years. The two areas had reported through two different management structures and have at times found themselves in conflict, although the strength of the bond ensured that this was a short-lived period of disruption.

The winning of two Queen's Awards - in 1986 for export and 1989 for technology - are the outward signs of recognition and are the pinnacle of the plant's historical success, as viewed from an external perspective. The ex-HR Director comments, "the management team focus more on the pioneering development of quality circles in the UK and the establishment of the Total Customer Satisfaction process (TCS) on the Northern site". This initiative is regarded as the commencement of the push towards "world class" manufacturing, established in the mid-1980s, and viewed by the

management team as the first step in the development of the revolutionary empowerment program. The most recent significant milestones are the adoption of the Lean Production Kaizen initiative in the mid-1990s and the introduction of the SS program from 1999 onwards, historical activity is mapped in **Chart 4.2.1**



Total Customer Satisfaction (TCS), the site's quality circle program and employee involvement initiative, was established in 1986 and evolved into a major driver in the establishment of a "Total Quality" culture. The TCS teams proved to be both popular and successful, and thirty-minute meeting slots were provided each week to progress projects or to brainstorm improvements. Basic training was given to the group members and staff support was readily available. The process did not take a strong hold in the staff areas, with very few groups in the engineering, purchasing or accounts function participating in the program. The shop floor historically had as many as 45 TCS teams working on line-based initiatives at any one time. Several

members of the management team noted a single criticism whilst being interviewed. They highlight a focus on the soft nature of many of the projects and the lack of ability to trace the benefits to the bottom line of the European business. The project teams are regarded as having made significant contributions to the work ethic of the employees in the facility over the last two decades. The more recent Six Sigma orientation of the management team focuses upon the weakness of TCS results and does not allow significant credit to be reflected upon the program. In its time, the initiative greatly developed operator involvement and interest, and recognition of the heritage of open-mindedness and change acceptance. The management of the time considered the initiative as very much a soft cultural development tool and not a hard business improvement program. Alongside the TCS program, an employee suggestion scheme was in place. This paid a financial reward for successful improvement ideas. Thus, operators' direct cost reduction or business efficiency improvements contributed towards the suggestion scheme and away from the TCS process. The conflict possibly strained the smooth operation of both processes, and ultimately this undermined the value of the TCS activity, which was phased out in 1996. The suggestion scheme was also abolished in 1998 after a two-year run-down period. The management team decreeing that all improvements or suggestions would be 100% retained within the business.

4.3 Lean Production & Breakthrough Kaizen

Case study A embarked upon a "Breakthrough Kaizen" process in 1996, in collaboration with leading international Time Based Manufacturing (TBM) consultant TBM inc. The initial workshop was completed at case study D and convinced the site

General Manager, of the benefits of establishing a Kaizen department and implementation plan to roll the initiative through the business. The area was headed by a Kaizen Manager, who aggressively targeted the driving out of waste from the manufacturing system. The initial workshop exercise and interface with TBM was supplemented with discussions with a number of experienced academics and practitioners. Dan Jones of Cardiff University delivered the keynote speech and stimulated significant discussion among the management team, with all agreeing to support the plant-wide rollout of the program. The introduction of Lean Manufacturing (LM) techniques in the late 1990s is noted by a number of individuals as causing significant rifts in the site management structure. Many members of the management team took several years to come up to understand the Kaizen initiative and the associated rolling program of manufacturing line changes. Two conflicting schools of thought evolved, within the management team.

1. – The do nothing element, resisting the need to change and evolve.

2. – The Kaizen supporters.

4.4 The Six Sigma Corporation

The Six Sigma initiative was launched globally by the parent company of case study A in 1998, championed by an ex-General Electric Black Belt, who had been recently recruited from a division of General Electric that had established a Six Sigma program in 1997. The SS process was adopted by the Corporation through the course of 1999, with implementation into all manufacturing plants in the manufacturing group over the next two years. The concept of Six Sigma had commenced at Motorola in the late 1980s and progressively developed through the 1990s at General Electric, with a

number of the original champions internal to case A having had initial exposure and training at GE facilities. The majority of the managers interviewed were of the opinion that the influx of GE management introduced a harder-edged cost and benefit approach to the case study facility and focused the management team on the development of a shorter planning horizon and a distinctly more dollar-orientated strategy.

The commitment to the Six Sigma process has been very significant in both financial and manpower commitment terms, with several million dollars being invested in training materials in the late 1990s and more than a million dollars annually in manpower to implement the training. The payback can be regarded as equally significant, with up to $100 million of project savings across the corporation annually being reported with the case study site yielding up to $16,000,000 worth of project benefits in 2002/3. The average annual saving declared by case study A after an audit process conducted by the central accounts function reflected around $8,000,000 per year in project savings. The supply base of case study A is recognised by the site management team as having contributed for many years to the advances of the facility, with the provision of historical annual cost reduction targets of 6% year on year and a shared history of continuous improvement in the European supply base. Working in partnership with the supply base, case study A has traditionally shared manufacturing technology developments, and as such they have been at the forefront of manufacturing developments via the partnership approach of the facility. The change management team considers that any industrial advances made at the site have traditionally been shared by the manufacturing facility and the first tier supply base, in the spirit of partnership and long-term commitment.

The future of the European assembly business at the facility had historically been regarded as the development of flexible assembly of professional products, focusing upon the service of the European market. A number of members of the change management team involved at this juncture considered the development of an Agile manufacturing base as an essential step to support the growing European business for professional power tools. Alongside the quest for Agility the company turned towards the Six Sigma business improvement tool and harnessed the power of statistics to advance the key business drivers, although the core business requirements, as considered by the change management team, did not change. They remain focused on delivering three core elements, highlighted by the global president of manufacturing:

1. **Cost Reduction** - The reduction of the total costs of the tools produced
2. **Zero Defect Quality** - Defined by the performance levels and critical success factors exposed by discussion and agreement with the key customers.
3. **Delivery 100% on time in full** – Regarded as a seamless delivery schedule to key customer requirements time phased and in full every time.

In an interview with members of the change management team they understood well that the methodology, tools and techniques of Six Sigma are not necessarily new, some of the techniques having been established at the turn of the last century. The improvement methodology adopted by the site shadowed the process that commenced at Motorola in the early 1980s, developing into the current shape of SS through the course of the early and mid-1990s. The change management team had been given an outline of the technique in a study tour of GE Super Abrasives in 1998, with this benchmarking activity beginning the level-setting process for the management team that would be involved in the change process over the years to come.

Within the facility, the compatibility of the S.S. initiative and the Lean techniques was recognised by key change agents, such as the site quality manager at the facility and the manufacturing Master Black Belt, very early in the benchmarking activity. The training material developed focused upon a complementary approach, combining the two processes into an early form of Lean Sigma. The management team recognised that to achieve the full potential of the C.I. initiative it was becoming increasingly important to develop a supply chain capable of performing at Six Sigma levels, focusing all significant first-tier suppliers to strive for this goal. The site Master Black Belt, commented that, "Failing to develop a supply chain capable of providing Six Sigma quality, cost and delivery would ultimately lead to the program failing. In the manufacturing facility, the standard manufacturing cost of assembled power tools was typically made up of up to 75% purchased components. They are delivered from a global supply chain, with increasing expansion into the Far East and China. The management team recognise the need to facilitate the development of a supply base capable of performing at Six Sigma levels."

Harry and Schroeder (2000) comment that, "One of the perennial problems associated with lifting an organisation's sigma level is that supplier companies think of themselves as producing goods and services. Yet most companies don't make all the components themselves; rather, they assemble products or deliver services created from many different parts or processes generated by other companies. As a result, the quality of a company's products or services is dependent on companies outside their control." The steering committee of case study A, being in unanimous agreement upon the need to build the foundation of change upwards from the supply base.

4.5 Development of The Lean Sigma (LS) Toolbox

A second site, Master Black Belts, comments, "We focused the introduction of S.S. into four distinct areas, with a distinct attack plan designed to penetrate each area, unlocking the potential of each sub system and delivering improvements across the total system." The four areas are as follows:

1. **Supply Chain Development** – both internal and external to the manufacturing location, up-stream and down-stream activity was launched across the logistical and supply chain. This covers areas as diverse as supplier capability to focus upon, and deliver, customer pack requirements and on-time, in-full delivery scheduling to customers and amongst the supply base, ongoing improvements in component capability, and year-on-year efficiency improvements reflected in cost reduction at a component level.
2. **Manufacturing Improvements** – improvements in all aspects of the manufacturing process and product performance assessment, including efficiency improvements, waste removal, Takt time development ("To the Beat of The Customer"- manufacturing product to the precise time-phased needs of the customer), product life assessment and Weibull life analysis (Statistical Analysis of product test failure as a predictor of product life).
3. **Engineering Focused Improvements –** design for S.S. implementation at the concept design stages of new projects, including the rollout of the skills through the entire engineering team to ensure that the principles of S.S. are introduced at the conception of the power tool design stage.
4. **Commercial and Financial Activity** – transactional training process implementation through the commercial areas of the business, focusing upon simple "Voice of the Customer" interpretation and attribute skills across all

commercial areas to concentrate upon the correction of errors in transactions and commercial activity.

The Master Black Belt adds the following comments: "The very definition of Six Sigma performance - less than 3.4 parts per million defects across the business processes of a site the scale of the facility (net sales value of around $600 million in 2002) - is difficult to imagine. When this is coupled with identification of true customer Critical to Quality (CTQ) features, we can envisage a process that will drive significant changes into the arena of manufacturing process control and supply chain management, yielding millions of dollars of benefits." The general manager of the facility, comments that, "new levels of performance are required from all areas of the business and new demands require ever more radical supply chain solutions. We are striving towards defect-free supply performance with ever decreasing levels of stock and inventory. To accomplish this, need a new toolbox, a blend of Lean and Six Sigma." In blending the Lean Production and Six Sigma developments on the case study site, the toolbox can be defined as attempting to provide a holistic approach to solving the problems of a complex and diverse global supply chain, building the lean production tools alongside the statistical problem-solving and analysis tools of Six Sigma. The toolbox could more accurately be termed a Lean Sigma (LS) toolkit, with access to lean production techniques alongside the methodology and structure provided by the twelve-step Six Sigma project management process.

In interviews, with the site Six Sigma introduction team, they feel that they have pulled together a number of proven statistical tools that are now well established at the facility. They have also introduced the rigour of the 4-phase methodology of

Measure, Analyse, Improve and Control (MAIC). The four phases are in turn given additional structure by strict adherence to the twelve sequential verification stages of the SS project management process. The MAIC structure is used with all projects and is documented as the technical information record and a conduit into the "live on site" process in areas such as the product FMEA. The 12 step process brings additional structure with the well-documented project management process bringing increased discipline and project management focus to the improvement initiatives witnessed at the facility. The statistical tools are tried and tested industrial practices with a proven pedigree of process improvements through the use of the basic steps of measurement, assessment, improvement and control for all project activity.

The twelve-step MAIC process provides a structured project management methodology to ensure integrity in the project delivery phase and strengthen the project management process in place at the facility. This is considered essential by the C.I. steering committee within both the L.P. and S.S. areas, and the author considers that projects that are highly focused upon statistical techniques require the additional focus at the commencement of the project to ensure the integrity of the intricate measurement phase. One Master Black Belt focused in the roll out process throughout the motors and components manufacturing section of the facility commented that, "Rigorous tools like GR&R (the assessment of measuring processes over time) have historically been performed as an exception, not as a first principle or mandatory requirement in the facility. Component and operator variation now have a simple tollgate process to guarantee measurement errors are rectified prior to progressing to analysis and improvement phases." Another Master Black Belt, employed in the manufacturing assembly area roll out initiative comments that, "without the rigour

supplied by the 12-step process, the C.I. team found themselves often reverting to type and jumping to the improvement phase of many simple projects. Throughout the facility we now aim to follow the discipline of the 12-step process and also to tie in the statistical tools with training in the practical assembly-based elements of the Toyota Manufacturing System (TMS) Kaizen, single piece flow, Takt time analysis, Kanban, mistake proofing etc. Basic training being covered in all areas with easy-to-access quick guides complementing the training manual and the workshop-based training structure, with the aim of delivering a total L.S. package tailored to the needs of the manufacturing facility and employees." In terms of the site-wide rollout and total training process of Six Sigma, the day-to-day use of first principle statistics is supported by the proprietary statistical analysis package "Minitab". This is noted by one Master Black Belt as, "essential to reduce manual calculations and as such reduce time, cutting down on the manual input to first principle calculation, while at the same time eliminating any calculation error".

In the opinion of the steering committee, the coupling of the LP process with the rigour of SS ensures that facility does not embark on Kamikaze Kaizen, as noted in the UK by Friedel (1999), and that the gains are maintained and built upon in a true incremental Kaizen approach, developing a supply base that is both agile and lean (Whitehead 2000) with Six Sigma capability operating in tune with the manufacturing cells.

The simple guidance notes used in training at the facility highlight the twelve-step process and table 4.5.1 structures the questions posed at each step of M.A.I.C.

	Measure	**Phase 1. Team Questions**
1.	Select CTQ characteristic	What area should I be working on? How do I link this to the needs of the customer? Can I trace the need back to a financial justification?
2.	Define performance standards	What am I measuring? What metric shall I use? What is the defect I am looking to find?
3.	Validate the measurement system	Do I trust my data? Have I proven GR&R? Do I have a Standard Operating Procedure (SOP) for the process?
	Analyse	**Phase 2. Team Questions**
4.	Establish product or process capability	How bad or good are we currently? What is contributing to this performance level?
5.	Define performance standards	How good do I or my customer want me to be? Can I translate this into a measurable number?
6.	Identify variation sources	What is causing the problem in the short and the long term? Do I understand all elements of variation present?
	Improve	**Phase 3. Team Questions**
7.	Screen potential causes	Which factors really will improve the current situation? Have we documented all the thoughts of the team on possible causes? Do we have a Pareto of possible causes?
8.	Discover the variable relationships	What are the best settings for all my factors and how does the process perform at this level? Do I have factors interacting?
9.	Establish operating tolerances	What must I do to ensure six sigma performances?
	Control	**Phase 4. Team Questions**
10.	Validate measurement system	Do I trust the performance factor measurement? Should I re-check my measurement process and GR&R?
11.	Determine process capability	How well are we able to control the key factors? What ongoing capability do I see?
12	Implement process capability	How can we ensure that improvements are sustained? How can we ensure we have established a rolling measurement of capability?

Table 4.5.1 – MAIC at Case Study A.

Case Study A commenced the rollout process of Six Sigma into the first tier supplier base from 1999 onwards and targeted the process of facilitating the top 100 suppliers' adoption of the Six Sigma initiative. According to the author's measurements to the

end of 2003, the strike rate shows significant penetration, having trained and approved 125 supplier "Green Belts" (This can be considered as the basic ten-day training course and the completion of the two initial improvement projects) and 27 internal purchase "Green Belts". Additionally, they have trained and facilitated five "Black Belts" (Reflecting ten days' training completed, with supplementary statistical skills and the experience of working full time in the introduction of Six Sigma inside a first tier supplier). The training activity was accomplished in the course of 2000/2003 and covered over 85% of the supply base by spend.

In an interview with one manufacturing Assembly based Master Black Belt dedicated to the tool assembly area, he considered that the key aim of the initial training process in the supply base was to establish a beachhead, capable of understanding the terminology and commencing the dissemination of the process into the supplier management team. He feels that it is imperative at this stage to select a candidate capable of understanding the complex statistical processes and with sufficient seniority to provide management support for the SS rollout. A number of candidates that have scored low on the initial assessment process have struggled on the training or rollout process, with the pace of introduction to the individual supplier suffering as a result. Prior to the commencement of the program, some statistical preparation is given, though ideally the candidate would have a technical background and a good grasp of the basics of IT. The candidate selection guidelines followed by the facility can be defined as follows:

- **Assessment of Candidate Status** - the selected candidate should have an appropriate level of seniority in the business to become one of the significant change agents in the facility on completion of the training activity schedule.

- **Thorough Grasp of the Concepts** - the candidate must have a basic statistical or technical background to allow him / her to follow and progress through the training material. This basic need for mathematical aptitude is essential to successfully complete the training activity.
- **Basic Project Management Experience** - they should be capable of practically leading a project team and supervising other projects in the rollout process to the work place.
- **Commitment to Change** - the candidate will ideally have a high degree of drive and enthusiasm and be able to preach the benefits of the SS process as an evangelist, winning both hearts and minds with technical facts and data.

The case study site developed the rollout concept through the late 1990s, with the initial training activity and mentoring process being backed up in key suppliers with an intensive Cost of Failure (CoF) assessment. The CoF process attempted to document the total cost of failure present in the first tier supplier, defining and documenting an area that has for some time been recognised as an essential element of supply chain management by a number of authors (Schmahl, Dessouky and Rucker 1997). The activity is supported by an audit team, and the onsite results are then used to construct a project based rollout plan, focused on the key areas of waste evident in the first tier supplier. This document forms the base for the supplier development process, and in the author's opinion, is a significant development step onwards from basic Cost of Quality (COQ) assessment processes previously used on site. The CoF assessment activity outlines the prime focus areas and possible areas of cherry-picking activity, whilst commencing the alignment of skills and training to help harvest the opportunities in the supplier's facility. The financial impact of failure in the supply chain has been noted by a number of authors. Bowman (1994) linked the cost of COQ

to issues in the supply chain, whilst understanding that a number of related factors (hidden activities) did not figure in the equation. In 1997, Bowman noted the magnitude of impact whilst assessing a more holistic model of COF upon the total logistics process. In line with the thoughts of Bowman, the author believes that the development of the COF process has helped to focus effort on the hidden factors at the facility and in the external supply base. The process exposed many poor or inefficient practices that had previously been considered as "accepted inefficiencies" becoming the norm over time in the value stream, both inside and outside the facility. This acceptance of waste in the system may well be evident in much of the Western manufacturing industry, elements of waste acceptance being recognised in the case study and in the satellite case study sites. The author's experience of working alongside the Toyota manufacturing system reflects the Japanese mentality of constantly chasing and eliminating waste (*muda*) in the system at every opportunity. The Cost of Failure (COF) process on site seeks to identify four key areas:

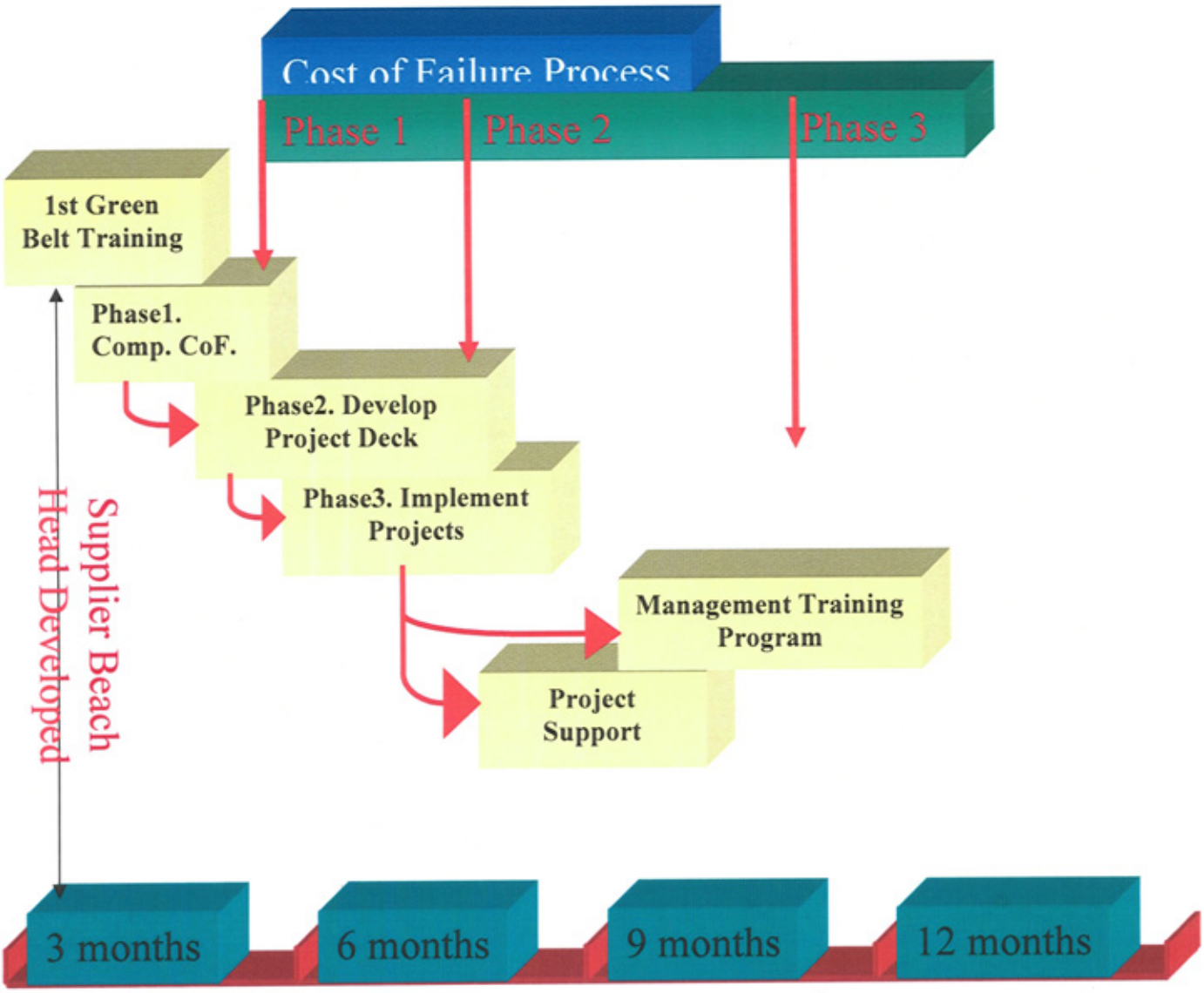
1. **Poorly Performing Areas of the Business** - areas of the business that are considered or measured as not working at Six Sigma performance levels and as such have opportunities for improvement in performance.
2. **Performance Metrics that Indicate the True Efficiency of the Process** – with metrics such as "Rolled Through Yield" (RTY) measuring the compound nature of the process, calculating the true end-of-line performance achieved by an assembly area, thus exposing the hidden factories. With 'Defects per Million Opportunities' (DPMO) computing the complexity.
3. **The True Financial Implications to the Site** - of performing at the current level and the priority areas of attack based on a Pareto assessment of the

findings. This is termed the "vital few" and is the focus of the attack plan. The remaining areas are known as the 'trivial many'.

4. **The Project Deck and Implementation Plan** - to be worked upon in the course of the first twelve months' activity are developed as a consequence of the previous three initiatives and form the initial steps of the SS introduction process and initiative rollout plan.

The cost of failure process has also been used by case study A in the first tier supply base as highlighted by Fig. 4.5.2

4.5.2 - Supplier Development Schedule Year 1.



In 2000, the case study facility established its own set of metrics and a process of measurement, and currently focuses upon the measurement of two prime areas.

1. **Financial and Supply Chain Productivity** – focusing upon the development of quality indicators and metrics to monitor supply chain improvements, with each measure being directly traced back to a critical indicator value.
2. **Critical to Quality (CTQ) values** - CTQs are defined for products and processes through the entire business, with all of the values then being combined towards a rolled up performance metric measure.

The full array of measures are arranged in the format of a company-wide dashboard for the facility, with all of the measures being converted into Defect Opportunities Per Million (DPMO) and then translated into a company-wide sigma value of plant-wide performance. The steering committee views the development of balanced scorecard approaches as essential to the true understanding of performance and direction.

4.6 Supply Chain Productivity Process

The facilities components supply chain has historically been tasked with delivering between 6% and 7% annual productivity. This is defined as year-on-year price reduction for all purchased components. The activity had been successfully supported through to 2003 with the delivery of a number of Six Sigma projects, stripping the *muda* from the supplier cost structure and attempting to deliver productivity whilst remaining profit-neutral to the supplier. This had been successfully achieved by the facility through the introduction of SS to the first-tier supply base, with a concerted roll out push generating up to $10,000,000 per annum in cost savings from the projects directly linked to a number of the Northern facilities key purchased

components. The measurement of cost reduction from the supply base is a hard dollar-based measurement process, reflected in invoiced price reduction delivered to the manufacturing facility. The top 100 suppliers had been challenged to engage in the process and deliver projects that may well contribute to quality improvement, supply chain flexibility and cost, although the ultimate measure for the first tier supply base remained invoice price reduction of purchased components. In interviews with the steering committee they feel several areas of site performance are improved by the first tier roll out activity, the key elements are as follows:

1. **Product Cost Benefit** – the $10,000,000 annual contribution of the first tier supply base reduces the actual cost of the tools manufactured at the facility.
2. **Component Quality Improvements** – a significant number of projects focused upon the resolution of long running component quality problems that had historically disrupted the manufacturing process on the site.
3. **Supply Chain Flexibility Improvements** – alternatively the project may contribute to stock reduction, supplier managed inventory, the introduction of time phased deliveries, line side direct to line deliveries.
4. **Development of the Tracking and Audit Activity** - the supply chain roll out process allowed the C.I. team to practice and fine tune the audit and project tracking process. The ability to audit project cost reductions is considered an essential element of the foundation of the SS process at the site by the C.I. team.

Suppliers' incoming quality performance was recognised very early in the process as having a significant impact upon the operation of the assembly facility. The Manufacturing Quality Director for the site, comments that, "any prospect of Six

Sigma performance is heavily influenced by the supply base. Concepts like Just in Time and Kanban become inoperable with processes that are incapable in the first or second tier supply base. The business fully recognised the impact of poor process capability upon the Lean systems in place in the organisation and directed resources and activity to drive this area forward." Throughout the rollout period the supply chain projects formed a significant element of around 45% of the total project workload (the "project deck", in site terminology) for the facility, with both inbound and outbound elements being focused upon from inside the assembly facility. One Master Black Belt comments that, "both areas have had extensive measurement and analysis applied to them in the selection and development of applicable metrics, coupled with improvement and control projects upon the vital few areas for improvement. Transport and Logistics is an area of rich pickings with significant financial bottom line impact; improvements in this area move very quickly to the bottom line of the business. Performance improvement metrics are in place across the supply chain and as the process continues to roll out through the supply base, substantial improvement are anticipated." The initial supplier training wave was completed in 2001 and first CoF analysis commenced later in the same year. Inside the key component suppliers, the change management team aimed to focus the supply chain effort upon the dual goals of:

1. **Successful Implementation of the Six Sigma Methodologies into the Key Component Supplier** – developing the culture of CI in the supply base.

2. **Rapid Transition into the Improvement Activity Phase** – ensuring that the cultural transformation translated into delivered dollars of cost reduction, transferred to the bottom line of the balance sheet and into product cost.

Twenty significant CoF activities were delivered through to the end of 2002, with the process continuing through 2003, prior to the plant assembly function transferring in the course of 2004. The following two completed projects highlight the typical supply base improvement activity at case study A, and the following summary highlights the size and shape of a typical project to be explored in the following chapters. In the interest of supplier confidentiality, in the reporting of the improvements and subsequent results, the suppliers will be referred to as supplier 1 and supplier 2. Both suppliers attended the initial SS / LS training waves in 2000, with several key staff members completing the ten-day basic awareness course and subsequent supplementary workshop activity program. The two individual businesses then progressed through to the commencement of the initial COF assessment phase, having completed elements of initial project activity. The key Black and Green Belts received additional mentoring by the training and development team and then progressed towards the delivery of more challenging, statistically detailed and technically advanced projects.

Supplier 1 is contracted to manufacture electronic circuit-boards for the facility and one major project, which set out to remove a manufacturing bottleneck process on a category A running item, will be focused on. The product was identified as business-critical to the site in 2000 by a supply chain risk assessment analysis, with any supply issues potentially having a significant impact on a number of areas of the business, with the potential to impact finished product production on a key high-running item. The activity commenced with the measurement and analysis phases of the twelve-step process, the team initiated the development of first principle measurement assessment tools such as GR&R (Gauge assessment consisting of both operator and equipment

review) as a first step towards the introduction of input process controls to replace the established output measurement controls on a time and performance-sensitive flow solder operation. The combined C.I. team implemented a fundamental change in the manufacturing norms in place in the business, with significant cultural movement from measuring outputs to measuring inputs and focusing initially upon the process of measurement to review if the equipment and tooling available was actually able to measure the process variation present.

The change process commenced with the restructuring of the existing workflow to introduce Lean, time-based methods alongside preventative input-side S.S. statistical analysis and control techniques. The combined approach of Lean and S.S. activity across the project allowed the tools of both techniques to be combined in one improvement activity at the supplier. The two threads of the L.S. improvement activity process are combined in this one project:

1. **Six Sigma Activity** - the S.S. aspects of the project aimed to radically change the statistical control mentality established in the supplier, monitoring the flow solder process input measurement in place of the previous methodology of process control of the output characteristics. All of the S.S. activity was founded upon measurement processes with proven GR&R performances and known acceptable variation levels. The new techniques controlled inputs, they also established a long term variation assessment process on site at the supplier and formed the pilot scheme to introduce the concept of long term variation assessment.
2. **The Lean Production Activity** - the area was transformed by workflow analysis and movement assessment, preparing the ground for a "Breakthrough Kaizen" exercise that transformed the production facility into a U-shaped Kaizen

cell, tuned to Takt time and single piece flow. The activity resulted in a significantly improved flow of production with a greater degree of volume flexibility and reduced manning requirements. The single piece flow approach improved the output quality by minimising the potential build-up of possibly defective components and introducing the rigour of a structured Standard Operating Procedure (SOP).

The completed and audited project resulted in a $375,000 annual cost reduction on the components supplied to case study A and a 60% floor space reduction in the first six months of the project at the supplier's assembly facility. There was an additional improvement to the end-of-line reject rate, which was reduced by over 50% in the first year of production, with the subsequent benefits to delivered component quality.

Supplier 2 is contracted to manufacture injection moulded components and sub-assemblies, and commenced a major project partnership with case study A in 2000 to part-assemble a lawnmower deck prior to shipment for final assembly, wire-up, test and despatch. Significant supply disruption through the first months of 2000 reflected the low output yields at Supplier 2's assembly facility, with the following key concerns being noted from the initial value stream audit activity:

1. **Low levels of Efficiency** – being achieved per operator against the previously anticipated performance level that had been used in the work quotation.
2. **Significant Work In Progress (WIP)** – could be considered as being evident at all assembly stations with little traceability of its origin or control. High levels of WIP reflecting a lack of understanding of the customer requirements.

3. **High levels of Wasted Operator Movement** – developed over time by the management and operators to work around bottleneck processes and develop a false flow to the work pieces.
4. **Considerable Levels of Scrap** – being evident in the assembly processes at strategically important points. The levels typically being high around the bottle neck process, contributing to the reduction of flow.
5. **Process Stoppages** - to rework damaged or defective components generated by poorly functioning sub assembly stages on the flow line. This activity both slowed the output down and failed to fully rectify the defective sub assembly.
6. **Poor Performance of Injection Moulding Tools** – tools and presses not achieving the desired performance cycle times through poor manufacturing practices and a lack of focus on injection moulding cycle time improvement.
7. **Frantic Recovery Processes** – focused upon throwing manpower at the issue through activity at weekends at peak labour costs. This activity often hid the scale of the issue of the problems in the short term and reduced the senior management focus until the issue impacted the accounts at a later date.

The activity can again be segregated into the two areas of L.P. and S.S. activity:

1. Lean Production Project Activity - the project team set out to radically streamline the assembly facility via Takt time analysis and a time-based assembly implementation plan (single piece flow methodology to the beat of the customer). The activity was structured around a number of workflow analysis workshops and a "Breakthrough Kaizen" exercise, overhauling the assembly of the most significant product sub-assembly (SA) components.

1. Six Sigma Statistical Tools - the key injection mouldings were reviewed by the team to consider the performance delta between anticipated cycle times and achieved

cycle times, rejection rate and general component aesthetics. Tools such as Taguchi / DOE reduced the cycle time whilst improving the consistency of finish and reducing the scrap rate of the large mouldings.

The activity resulted in the reduction of the total labour requirement by 28 full time employees per week whilst improving output, service level and quality. This exercise generated an audited annual financial saving of $350,000. Labour reduction of this nature requires careful handling and the voices raised against the C.I. process in this instance highlight the technique as purely a method of reducing the workforce. This activity encompassed many of the statistical S.S. analysis tools and was aided by the establishment of a "Breakthrough Kaizen" program with the aim of the initial exercise being to redesign the workflow and manning requirements of the SA area. The team introduced a process of continually monitoring of the work in progress (WIP) via statistical analysis techniques throughout the activity. The completed and improved S.A. assembly operation resulted in a new running methodology, performing at a balanced Takt time (Takt time is the beat of the customer's true requirements at single piece flow) as opposed to the "feast and famine" performance relative to the building of products for stock. The supplier can be considered as embracing the now established L.S. methodology. The examples highlight the typical projects rolled out to the supplier base and the mix of L.S. tools and techniques used in the C.I. process. The typical learning's of the two project activities can be summarised as follows:

Significant Financial Opportunities - both of the above projects highlighted significant financial returns as well as delivering quality and efficiency improvements, cost benefits were reflected in reduced component invoice price to case study A.

Improvement in Suppliers Quality Delivery Performance – both of the projects had a significant history of quality concerns resulting in production disruption and associated financial impact. The resulting performance of both projects delivered close to 100% defect free performance.

Training Opportunities and Skills Translation – the C.I. team stressed that both of the above projects had helped establish a beach head in suppliers 1 & 2 and helped smooth the way for additional project activity and training opportunities.

Fundamental Measurement System Development – both projects commenced with measurement system activity to establish a new level of focus on the importance of measurement in the project through steps one to twelve. The C.I. team constantly stress the importance of measurement system development as the foundation of any improvement project.

Maximum Space Utilisation – the projects delivered a number of benefits that are not typically reflected as financial results and the benefits of generating available space are one of the most significant.

Development of a Systematic Improvement Process – the initial projects in the key first tier suppliers of the case study were used to establish an accepted improvement process structured along the lines of the 12 step project process and benefiting from the tools and techniques of both Lean and Six Sigma. The use of the more holistic L.S. project process on the first high profile improvements attempted to establish the activity as the norm in case study A's dealings with first tier suppliers.

The Establishment of New Workplace Systems – the introduction of simple workplaces management systems such as the Japanese 5S process were pioneered through the two projects and the C.I. team aimed to use the pilot scheme as a spring board to launch the initiative across the supplier's facility. Both projects established

an introduction schedule for techniques such as 5S across the general facility, initially targeted towards the key manufacturing areas producing components for case study A. **Evidence of the Synergy of the Skills of Lean and Six Sigma** - the two projects practically mixed the skills of both Lean and Six Sigma and the success of both projects was founded upon the blend of tools, techniques and project management processes drawn from both schools.

4.7 Lessons Learnt From the Introduction of S.S.

The lessons learnt from the introduction of Six Sigma are many and varied, as would be anticipated and expected from any program that required such fundamental cultural change in an established manufacturing facility. The introduction of this primarily American continuous improvement development process into Europe has highlighted many of the cultural differences between the two industrial nations and the practical experience of rolling out the process highlights the need for cultural sensitivity. The Six Sigma banner has been adopted by many of America's largest corporations and has received extensive positive coverage in the major US journals and business periodicals. The positive message of Jack Welch translates across the American corporate world, and adds significant credibility to the SS process at all levels.

This has not historically been the case in Europe, with little exposure to Six Sigma through the 1990s. Recent years have witnessed a number of European and global corporations rolling the process out across Europe. This removal of the established industrial inertia has subsequently led to a rollout to the first and second tiers of the

supply base in Europe and the acceleration of the European development cycle. A number of key lessons can be learnt from case study A's supply chain initiative:

1. **Possible conflict with Established Supplier Processes** - case study A discovered a broad spectrum of supplier responses, ranging from willingness to transform the total business philosophy towards the adoption of the initiative as the CI tool of choice through to refusal to consider or discuss the SS approach because of feelings that the initiative will conflict with and detract from the established practices in place.
2. **Poor Levels of Lean Sigma Awareness** - the main reluctance discovered by interviewing the key decision makers in the first-tier supply base was frequently based upon a lack of understanding of the principles and the mistaken view that the approach would clash with the current business improvement initiatives established and operating inside the existing continuous improvement structure.
3. **Different Levels of Acceptance** - the response has been linked to a number of pertinent factors within the business, with supplier organisations that are linked to the automotive industry or existing as European branches of an American corporation actively seeking training from case study A and fully accepting the program, whilst the more traditional European supply bases have attempted to ignore the activity, buying time and hoping it would go away.

The terminology introduced from the USA may have proved to be off-putting to a European audience, with distinct martial arts, "super hero" connotations. A number of European companies have subsequently decided upon differing titles. Case study C are using the terms "Champions" and "Experts" within a package they are supporting, with the title being known internal and externally as the Lean Sigma project. Case

study A has accepted the adoption of the full terminology of the SS initiative and has chosen not to re-package the improvement process as Lean Sigma, preferring to discuss it externally with all interested parties as a S.S. drive. In contrast, Rank Xerox are using the term "Variation Reduction Engineer" in place of the title "Black Belt", as they feel this terminology will be more accepted in Europe and the title will have a closer link to the established Lean heritage.

The initial measurement phase at case study A proved to be problematic in the manufacturing facilities, with a number of processes reflecting difficulties in achieving acceptable GR&R results (a measure of a gauge's ability to repeat a measurement for a single operator and then perform repeatedly with differing operators). The initial survey of the measurement activities undertaken on site reflected over 4,500 GR&R studies, with the readings revealing about 25% unacceptable GR&R results. Significant measurement process improvement has been required upon a number of the measurement process fundamentals, this activity taking place in step three of the twelve-step process and as a fundamental element of any progress towards the improvement stages in the twelve-step project completion process.

The author witnessed the first signs of employee initiative fatigue at this stage of the launch process, with the initial enthusiasm being tempered with comments such as, "how long will this one last?" resounding from the manufacturing facility and the first-tier supply base as the process was launched. The European supply base could be considered as initially watching and monitoring the progress within the case study manufacturing facility prior to committing to the acceptance and rollout of the SS

process. A significant number of the first-tier suppliers needed convincing of the longevity and sustainability of the initiative, and as such a number of early problems can be highlighted:

1. **The Initial Calibre of the Proposed Candidates** – could be considered as below the initially anticipated level, with candidates proving not to have the authority or management presence required to roll the process out in the supply base.
2. **The Reluctance of the Senior Management Team** – a number of suppliers could be considered as resisting attempts to convince them to step forward as candidates for training and development. This possibly reflects a lack of confidence in the initiative and a degree of fear at starting to learn the technical material of S.S.
3. **Purely a Quality Focused Program** - a number of the senior managers in first-tier suppliers in the European supply base considered the program as purely a quality initiative, as opposed to a holistic business activity. This misconception at times slowed the initiative down, reduced the management commitment and limited the talent pool made available for training.
4. **Limitations of Teams Confined to Technical Staff** - the proposed introduction teams had tended to be selected as purely technical teams recruited from the facilities quality organisation, thus limiting the pool of skills to a small portion of the management team and limiting the initial impact of the initiative.
5. **Alienation and Company Wide Buy In** - the selection of the quality team as the first team to be trained and as the roll out candidates tended to alienate the rest of the business and further isolate the project from the facilities other departments and also the rest of the business.

6. **Mixed Teams Increased Company Wide Buy In** – roll out teams constructed from a site wide team tended to generate a greater degree of company wide buy and a boarded perception of acceptance.
7. **The Importance of Candidate Calibre to Company Wide Acceptance** – the initial candidates selected severely limited the opportunities for business-wide rollout and slowed the acceptance of business-wide projects if they were not of an appropriate status, calibre and strategically selected from across the management structure of the business.

4.8 The Next Steps For The Lean Sigma Process at Case Study A

In 1999/2000, case study A commenced a process of first-tier development with all key suppliers (90% of spend) to train and implement the Six Sigma initiative. The initiative had both tactical and financial motivation, with anticipated component quality improvements and financial project returns forecast. The initiative succeeded delivering over $6,000,000 of annual audited savings and resolving a significant number of quality issues. The plant efficiency performance measured as weekly output measured against the theoretical maximum output accelerated from a historical hard limit of around 80% to highs in the area of 94% through the course of the study period. The term Lean was not used in the title of the initiative rollout at case study A, as the corporate introduction team believed that Wall Street would not look favourably upon a perceived change of focus, and corporate America, led by the likes of G.E., can be considered very much S.S. orientated. In the author's opinion, the lack of the term Lean in the initiative should not be allowed to impact the material or Lean content in the training and rollout material in any such launch project. Case study A

adopted an open stance on the initiative as a Lean Sigma drive in 2005 and all current material reflects the blend of the two initiatives.

In discussions with the management team at the Northern facility, the development of the "World Class" toolbox, holding all of the lean production skills alongside the statistical skills and implementation methodology of Six Sigma, was viewed as key to the future of the C.I. initiative in the manufacturing plant. The LP process would become the vehicle to deliver optimum costs and defect-free quality whilst maintaining 100% delivery strike rates. The process of Cost of Failure (CoF) assessment and project development targeted the attainment of optimum cost structures (Focused towards delivering costs in line with Chinese importation costs from within more sophisticated western manufacturing locations). The change management team aimed to combine a "world class" cost structure with defect-free quality and right-first-time delivery potential in a bid to remain competitive in an ever more cut-throat global power tool market. The process continued to roll out through 2002 / 03, with the top 100 suppliers encountering varying levels of activity. A number of minimum actions had been defined for all the key suppliers, with a series of additional activities defined from each commodity group of suppliers.

In the increasingly competitive power tool market, case study A targeted Six Sigma programs towards the reduction of finished product inventory, and decreased lead times to customers post manufacturing. They improved component cost, quality and delivery, and enhanced flexibility in the "front end" supply chain process. The waste removal and increased flexibility delivered by the Six Sigma process aimed to help negate the threat faced at each power tool price point. The change management team

recognised the need for the full facility to drive towards Lean stock holdings inside an Agile manufacturing system that could flex and change to meet the needs of the customer. With the facilities project deck aiming to cover all of the areas of exposed opportunity, breaking out from the heartland of Engineering and manufacturing and focusing upon pan business improvements with plant wide improvement teams. The typical project improvements can be summarised as follows:-

1. **Cost Focused** – typically focusing on areas of opportunity highlighted from the pareto constructed in the Cost of Failure assessment, commencing with the greatest element of opportunity. This approach commenced the spread of project workload through the facility and exposed previously untouched diverse areas such as

- Invoice Clearance and Payment Initiatives
- General Contractual Terms Improvement (movement from 30 days payment to 90 days payment etc.)
- Development of Supplier Managed Inventory
- Reduction in Component Commitment Times
- Energy Consumption Reduction
- Energy Procurement Initiatives
- Waste Disposal Costs
- Consumable Procurement and Usage Reduction
- Reduction In Temporary Workforce Requirements
- Significant Focus on Absence Reduction Through Back to Work Initiatives
- Floor Space Reduction on Site to Eliminate External Storage Requirements
- Transport Cost Negotiations inline With a General Reduction of Shipment

2. **Quality Focused** – the quality activity aimed to spread the activity through all areas of the business with an ever increasing focus on process integrity alongside the

typical component or product quality improvements. The approach included a focus on the following areas:

- The Development of a Plant Wide Process Map
- The Assessment of Weak Areas and Priority Focus Projects Across the Plant
- Value Stream Assessment Mapping Activity to Focus on Key Bottlenecks
- Measurement System Analysis and Improvement
- Measurement Integrity Activity and Calibration Focus
- Rolling Process Capability Improvement Activity
- Increased Usage of Application Based Reliability Testing Programs (testing tools in true usage applications)
- Driving Field Testing Activity and Increased Product Field Placement
- Increased Stress and Strain Assessment and Mathematical Modelling on Performance via Weibull Testing Activity
- 5S Workshop Management

3. **Deliver Focused** – the focus upon product delivery aimed to cascaded projects through the manufacturing and delivery value stream looking to improve capability and efficiency at every step of the process. The typical projects are as follows:

- Machine Uptime Focused Activity
- OEE - Overall Equipment Efficiency Focused Activity
- Injection Moulding Cycle Time Reduction
- Injection Mould Tool Set-up Time Reduction
- Production Line Set-up Reduction
- Production Line Change Over Time Reduction
- Single Piece Flow Activity
- Movement Mapping and Improvement Activity

- Rapid Picking and Pick to Light Activity
- Stock Turn Analysis
- External Buffer Stocking Assessment

In 2000, the general manager, commented that, "the customer had historically paid for the waste in the logistical process; he is no longer willing to do so. Companies will remove CoF or risk losing significant market share to the companies that have successfully implemented Six Sigma in the Mid to Higher Price Point (MPP/HPP) bracket whilst being undercut in the cost-conscious consumer product arena by a growing band of Chinese 'own brands.' we have little to lose and everything to gain."

The management team at case study A feel 2002 witnessed major marketplace change in the UK power tool industry with the establishment of B&Q's own brand label, Power Pro, and a significant amount of the power tool market transferred from companies such as case study A towards this new entrant into the UK tool market. The penetration of the new B&Q brand in the consumer power tool market recorded over 30% market share within three months. B&Q had commissioned a number of Chinese power tool manufacturers to develop a full range of 50 products. They then harnessed the tools with the established distribution network of DIY market leaders, B&Q, focusing significant investment in advertising and awareness to generate customer footfall towards prime cost position power tools with guaranteed premium shelf space in the largest DIY retailer in the UK. Clever advertising and placement witnessed tools being placed with the around-the-world yachtswoman Ellen McArthur in 2003 as she manufactured a new boat to withstand the most severe of Ocean tests (Lloyd 2003).

This initiative was rapidly followed up by a number of other significant European retailers, continuing the expansion and influx of Chinese "no name" brands into Europe, supported by sponsorship from well-established retail houses. The response of case study A was swift and wide-ranging, with announcements of the closure of the assembly facility and a movement of the production lines and equipment to the Czech Republic. This activity commenced at the start of 2003, and by the end of December the production facilities required to produce over 14,000,000 power tool products had moved into a new facility in the Czech Republic. The site retained facilities to manufacture motors components and continued to function as a design centre and European reconditioning facility. The senior managers comment that the move aimed to fill the growing product gap at the bottom end of the power tool market that had been exposed by the "crash entry" activity of major European retailers partnering with Chinese no names and B-brands. Usti ramped up power tool production through 2003 and established itself as the low-cost assembly facility for the construction of power tools for the European market through 2004 / 5.

The Plant Manager, in the Czech facility quoted in conversations with CzechInvest comments, "The strategic decision of case study A is to open a manufacturing plant and invest in the Czech Republic and this is key in ensuring that our competitive edge is maintained in the European marketplace. One of the decisive factors in choosing the Czech Republic was the good logistics links to the European Union." Mark Tran, (2002) in his article for the Guardian, highlights a different angle under the headline "Power tool manufacturer cuts jobs in Czech move." The focus is very much upon the location of the Northern facility, which is in the constituency of Prime Minister Tony Blair, and the use of the plight of the case study as a parallel for UK manufacturing.

> "Power tool manufacturer plans to axe nearly 1,000 jobs and transfer work to the Czech Republic, it was announced today. About 550 production and office jobs will be cut from the factory, by the end of 2003 and the contracts of 400 temporary workers employed will not be renewed. This is the nature of the international economy."

The economics of the new competition, driven by companies such as B&Q, have transformed the established status quo of the consumer power tool market, and a six-month period of rapid change in 2003 significantly altered the well-established status quo of the market. The plant manager, comments on the competitive pressures in 2003, "Global competitive pricing pressures have been a key factor in our decision to make these changes", adding that the redundancies would be achieved through a voluntary redundancy scheme and, where necessary, compulsory cuts. Workers affected by compulsory redundancies would be offered help in finding other jobs and the business would try to transfer employees to other sites. The redundancies through the course of 2004 would leave about 450 people at the plant to focus upon the manufacture of motors and components as well as the design and engineering of new products. Through 2004, the facility operated with a workforce of 450, in comparison to the 2,000 employees previously employed on the manufacturing site.

The move to Eastern Europe formed one element of a manufacturing global strategic development plan agreed by the head office in the USA, containing a comprehensive plan of phased facility developments and expansions in low-cost assembly areas such as Mexico, Brazil and China and factory closures in the USA. The economics of

assembling power tools in the UK and America have ultimately swept aside the benefits delivered by the C.I. activity in the threatened plants in case study A's global manufacturing network. At least in the short term, financial benefits are gained against a reduction in strike rate to customer and quality levels. Wall Street, however, views the move as overwhelmingly positive in every respect, and the share price reflects this confidence.

The profound nature of the changes in manufacturing strategy is highlighted by the Businessweek journalist Amrit Tewary (2003) tipping case study A as a strong buy in 2004/5, focusing much of his judgement on the global restructuring program. Tewary highlighted the positive impact on Wall Street of the message of cost cutting initiatives, be they tied into efficiency initiatives or movements to low cost economies. The message to Wall Street carried the same significance: cost cutting is viewed in a positive light and share prices will be rallied by it. Amrit Tewary comments:

> "We expect a significant near-term earnings catalyst from its disciplined restructuring program, launched in 2001 and set to be completed by the end of 2004. The plan is estimated to cost a total of $170 million (of which $150 million has already been spent) and should generate $100 million of annualized cost savings by 2004. We have been impressed by the results to date. Despite weak end-market demand and inventory reductions at key retailers, the power tool manufacturer has been able to expand operating margins by closing inefficient plants and moving more of its production to countries with lower labour costs. We expect it to keep lowering its fixed-cost base through these

restructuring initiatives, thus making its future earnings more resistant to cyclical economic downturns than those of its peers. In addition, moving much of its production to low-wage countries will likely free capital and resources for investing in new product development and productivity initiatives."

Alongside the restructuring activities, Tewary (2003) also focuses on the C.I. initiative alive in case study A. In the article "Tooled for Growth", he focuses his attention upon the sizable impact that Six Sigma tools and techniques have had over recent years, highlighting the many additional benefits to the supply chain efficiency performance in recent years. Enhanced quality perception and reduced warranty return rates are also noted, alongside the $100 million annual project based savings the Six Sigma initiative has delivered. The question of whether the quality improvements or business efficiency activity are translatable to new facilities in low cost labour economies is not raised in this or subsequent articles. Many business analysts consider that the move will have significant financial savings, with apparent disregard for its impact on factors such as warranty costs or supply chain inflexibility.

A number of alternative implications require consideration in contrast to the finance-only perspective of the Wall Street analyst, as follows:

- **Possible Increased Warranty Costs** - via product breakdown inside of the warranty period, driving up the failure cost for the business as it transfers to low cost economies with a reduction in the skill base and experience.
- **Problem Resolution Periods** – extended problem-solving timescales through the loss of tribal knowledge and system breakdown.

- **Supply Chain Extension** – increased supply chain costs applicable to the extension of the supply chain process with increased transportation times and increasing quantities of stock.
- **Reduced Flexibility** – extended order-lock periods into the low cost manufacturing plants with the subsequent reduction in order flexibility to react to changes in customer requirements.
- **Production Batch Size** – increases in the average production batch size in low-cost labour facilities and subsequently higher stock levels.
- **Increased Product Obsolescence** – one of the consequences of the extension to the supply chain is the inevitable increase in the degree of product obsolescence resulting from higher stock levels and reduced flexibility.
- **Communication** – inevitably, the movement towards a low-cost economy and Far Eastern suppliers has strained the communication paths and increased the timescales in terms of product fixes, modifications etc.
- **Product Recall Possibilities** – the stability and consistency of low-cost products can be considered to increase the risk of product recall, through failure or safety concerns. The risk may well be heightened by the European General Product Safety Directive enforcement in the UK in 2005 requiring any significant safety issues are reported to the department of Trade and Industry for recall consideration.
- **Brand Name Damage** – the consequence of the previously noted items could well result in increasing damage to the brand name and the negative impact of the above will be very difficult to correct in the short term.
- **The Inability to Cost the Damage / Impact** – many of the above items can be considered as adding cost into the business, without being accurately

considered or forecast at the time of the decision to move. The hidden costs are subsequently not rolled up and the expectations do not reflect the fully burdened product cost.

4.9 Migration Path

The active migration path of case study A can be considered as a progressive set of evolutionary steps from the methodology of basic T.Q.M. towards a system of Lean Sigma C.I. with a considered series of milestones throughout the path. The journey can be considered as an incremental one with a number of techniques and initiatives forming building block along the path to L.S. as follows:-

- **The Establishment of Mass Production** – the site established in the mid sixties founded much of its development on mass production with small variation in the number of tools and products produced and a constant push for higher volumes. The facility produced tools in two distinct seasons with a high volume garden product season running through to the early part of the summer and a labour transfer to indoor power tools to pre-build for the Christmas period. One anecdote collected from a production supervisor focused on a motor armature produced in low volumes in the 1970's by the facility being manufactured in a run of 10,000 to save on set up time. The unit was discontinued in the mid eighties with 6,000 still in stock and destined to be scrapped off.
- **The Development of the T.Q.M. Facility** – the roll out and use of techniques such as quality circle deployment, task force problem solving and worker empowered teams in the eighties highlight the steps taken by the

facility to adopt the principles and practices of T.Q.M. The activity ran across the entire facility and helped establish a foundation of C.I. on site that would later serve as the ideal grounding for the development of Lean. One of the facility general managers interviewed agreed the T.Q.M. initiative had prepared the ground for the growth of Lean, but did not feel the T.Q.M. initiative had contributed to the bottom line of the business with many projects impacting the softer side of the business. The examples used to describe his thoughts, reflect quality circles meeting once per week in works time and planning new coat hangers and locker space.

- **Lean Production** – the introduction of the tools of Lean Production commenced in the manufacturing facility in the early nineties with developments of 'Just in Time' initiatives and Kan Ban activity. The Lean techniques at this early stage could be considered to be sporadic with little connection to the business objectives, although activity such as supplier component collection 'milk runs' delivered tangible benefits. The breakthrough Kaizen activity of the mid nineties reinvigorated the Lean push and helped to establish the full spectrum of Lean tools from the base of 5S development, Kaizen Cells, production to the beat of the customer and a continued drive towards waste reduction. The investment in the roll out activity was supported by the establishment of a Lean / Kaizen department, staffed by a senior manager and four permanent training co-coordinators. At the height of the roll out activity one production area per week was proceeding through the 'Breakthrough Kaizen' program.
- **Agile Methods** – the change management team of case study A consider the theme of Agility as being present from the early nineties, with the

manufacturing facility decreasing the product order locks from six weeks to one week in the late nineties whilst the product complexity increased. One senior planner considered the product mix complexity had probably increased three fold in the same time period, whilst the customer strike rate improved from 95% to around 98% first time in full.

- **Six Sigma Introduction** – the S.S. initiative commenced initially in the manufacturing assembly areas from the late nineties onwards and rapidly spread plant wide with initial focus upon the deployment of the Cost of Failure (waste assessment and opportunity exposure program) and the development of the basic statistical tools in engineering (Design for Six Sigma) and commercial (transactional Six Sigma) areas. The initial pioneers coming from quality and engineering backgrounds and bringing a degree of knowledge on the statistical tools and methods. A number of the first wave of Black and Master Black Belts having previous skills and training in Lean methods and active participation in the Kaizen initiative, the synthesis became readily evident and the first steps towards Lean Sigma were taken.
- **Lean Sigma** – The facility and corporation now consider themselves to be actively employing the Lean Sigma initiative having commenced locally in 2001 and re-branded the global initiative 'Lean Six Sigma' in 2005. The initiative banner has now changed three times in a decade, although the researcher considers that working practices remain focused around the common sense approach to C.I. problem solving, with the appropriate improvement tool being selected for use regardless of initiative title or the management improvement school it is attributed to.

4.10 Satellite Case Study B

Case study B has been selected as one of the satellite supporting case study sites and the facility fulfils many of the requirements for a longitudinal qualitative assessment. The key criteria identified are as follows:

- Access to a key respondent, available to work with the author over the length of the case study coupled to existing contacts in the facilities management team.
- Case study B has a history of continuous improvement initiatives throughout the last fifteen years at the case study manufacturing site.
- Progressive and open-minded management team, willing to share good practice.
- An organisation that is open to change.
- Case study B is a well-regarded "Blue Chip" business, leading the market in its own field, the design and manufacture of specialist and bespoke lighting fitments.
- The business is facing an increasing array of challenges, with intense competition from both external manufacturers and sources internal to the lighting group.
- The business is reflective of an individual market segment, though it faces many of the same challenges as the key case study.

The author has historically had links with the facility and this privilege has allowed access too many areas of the business and also excellent communications with the management and the shop floor operators. This has granted a good insight into both the higher-level strategic intent of the business, and has also allowed excellent access to all subsequent levels of the facility. The author has taken a positivist stance in the research in contrast to the action research activity of case study A. the research has been performed by observing the change process in the facility and gaining practical

experience of the process of change implementation on-site over recent years. The case study site in the North of England has a significant history and culture of change management and it can be recognised as a progressive manufacturing location. The site has striven to stay ahead of the competition over many years, through progressive management and a culture of Continuous Improvement (CI) in its manufacturing techniques.

Case study B is a leading global manufacturer of lighting solutions in both the consumer and the professional field, and the case study facility has historically been the most prolific production site in the parent group. Many similarities can be drawn between the two manufacturing sites of the case studies A and B:

1. **Traditional Assembly Activities** - the workforce of the assembly area is predominately made up of female operators, supported in component machining by traditional male setting and engineering skills.
2. **Highly Dextrous Skills Sets** - the assembly of lighting has many similarities to the assembly of consumer power tools, with typical demands on dexterity and assembly pace as key attributes. This has attracted a mainly female workforce in the assembly areas to perform the demanding wire up operation.
3. **Common Pool of Workers** - the close proximity of the two sites has generated a common labour pool with many operators at the Lighting site having relatives working assembling power tools.
4. **Similar Development Paths and Common Roots** - the two improvement cultures have had many parallels over the years and both companies developed from a common Total Quality culture in the 1980s.

5. **Global Internal Competition** – case study B competes in the highly competitive European lighting market, although it also faces global internal competition. The intensity of the internal competition can be compared to the internal threat faced by case study A over the last five years.
6. **Historical A Brand Competitors** - both businesses can be defined as mainstream A-brand businesses that have traditionally competed against European rivals in a historically European dominated market.
7. **New B-Brand Attack** - Chinese B-brand competition and increasing low cost internal competition has significantly changed the game for both facilities.

4.11 Company Background

The Northern facility forms a part of a large German manufacturing group of companies and lays claim to very strong brand recognition in the professional lighting market, with an established turnover of EUR 500 million. Case company B has its roots in Europe and it is the second largest light fittings supplier in the European market. Being the market leader in the UK and has strong market positions in France and the Nordic regions. The group is also one of the leading suppliers of light fittings in the Australian and Hong Kong markets and is constantly striving to develop further its presence in the Far East, particularly in China and Singapore. The Far East presents a rapidly emerging market that case B feels well placed to exploit. This strategy brings it head to head with low-cost Far East manufacturing locations and competitors.

The plant manager, comments upon the corporate vision: "Our strength lies in our ability to consider the international dimension when it comes to design and development of our products, whilst at the same time fulfilling the requirements of customers and markets with the knowledge and understanding of a local supplier." The business is focused on professional and industrial applications, including surface and suspended fluorescent fittings, emergency lighting, spotlights and down lights, indoor decorative lighting, industrial lighting, road lighting, outdoor amenity lighting and column floodlighting, fibre-optic lighting, airfield and airport lighting. Internationally, it produces over 20,000 product items and product variations available to its customers. The 2001 Product Catalogue publication contained over 200 individual product ranges, of which an estimated 300 product varaints are in production at any one time at the facility.

The case study manufacturing site can be considered as a traditional British manufacturing brown-field location with a legacy of industrial relation problems and trade union disputes through the 1970s and 1980s. It has had considerable experience of C.I. activity, and the last 15 years can be split into three distinct phases:-

1. **The Development of a TQM / Basic Lean Production System** – established across the facility through the period from 1990 - 1995
2. **The Consolidation of Lean Manufacturing Practices and Techniques** – developed and consolidated on the manufacturing site of case study B through the period from 1995 - 2003
3. **The Development of Six Sigma and the Integration of the Process into the Lean Sigma Mentality** – the synthesis of the two techniques has developed in cases study B across the full facility with the blending activity ongoing.

The manufacturing Manager comments that the local management became increasingly aware through the late 1980s that survival required a manufacturing metamorphosis in all areas of the site. He feels that the change process marked the commencement of an industrial revolution on site that penetrated every area of the facility and permeated to every level of employee. The author witnessed much of the change from a number of regular study tours conducted at the lighting facility over the last seven years, and although unable to comment upon the facility in the 1980s, tremendous progress was recognised through the development period of the study. In the mid 1990s, the facility had independent confirmation of the turn around, it gained a number of regional and national awards in this period. The growing reputation also helped it to become one of the most visited sites in the UK as an element of the "Inside UK Enterprise" program, run in conjunction with the Department of Trade and Industry (DTI). In the previous ten years, the facility had progressed from the status of a very traditional British manufacturing company. The management team fully understood that they were facing a "change or die" situation, and they have accomplished a massive cultural shift, fully embracing the need for change. Whitford and Bird (1996) celebrate the facility, commenting on the general change witnessed:

> "The radical change and improvement the plant has undergone is a clear example of what can be achieved when workers and management understand the problems facing them are caused by competition from the international market place and not each other."

The realisation of the need to change formed the basis for the establishment of a change of culture in the 1990s. The business was setting out upon a journey, through the first steps of establishing an environment of Total Quality, the development of

Lean Production techniques and the continued development of the facility along with the acceptance of a C.I. initiative and culture. In the early 1990s, the company manufactured professional lighting and control equipment in eight global facilities and employed over 4000 staff, more than 1000 of whom were employed at the design and manufacturing centre at the facility selected for this case study.

The lighting site has been instrumental in the drive to modernise the global manufacturing centres of the parent business, leading the way in the introduction of Continuous Improvement manufacturing methodology. According to the site manufacturing manager, this facility has been the catalyst for the entire business throughout this change process, his passion gives a strong indication of the commitment of the manufacturing team to the development of a progressive C.I. culture. The design facility, relocated from London and now stands upon the site of the old warehouse, which is no longer required, as a series of C.I. projects improved process reliability and removed the necessity for the £4,000,000 worth of inventory traditional held on-site in the 1990s. This has been replaced by a state-of-the-art design and test facility linked directly with the manufacturing plant. The business is now focusing its efforts upon linking design and manufacture to deliver the speed and flexibility that the market demands. The process efficiency and stock reduction program delivering the following benefits:

- **Inventory Reduction** – close to £4,000,000 of inventory had been removed from the balance sheet.
- **Reduction in Excess and Obsolete Inventory** – the activity drastically reduced the annual review of obsolete stock and negated the need to scrap slow moving or redundant component and finished product stock.

- **Reduced Labour Costs** – significant financial savings were generated by removing the need for component and finished product inventory.
- **Increased Space On Site and Greater Asset Utilisation** – the UK business established it's design centre on the footprint of the old warehouse and eliminated the need for a costly additional facility, whist improving the linkage of design and manufacturing.
- **Improved Manufacturing Process Efficiency** – the efficiency, change over, and scrap reduction projects through the manufacturing facility eliminated the need for large batch production and dual product planning. Allowing the facility to produce small batch runs with quick set up and change over times.
- **Reduction In First Tier Suppliers** – establishing a reduced supplier base with substantially increased leverage increased case study B's ability to leverage costs, reduce stocks, introduce the principles of supplier managed stocks, extend payment times (if required) and to get closer to the supply base.
- **Delivered A Visible Sign** – highlighting the C.I. works.

Between 1979 and 1985, case study B consolidated a number of sites into the Northern facility in an effort to increase the plant's volume and thus reduce overhead costs. Despite the economies of scale and new investment in high volume production equipment, the order book continued to reflect a business in decline. By 1990, the competition was leaving them behind, and this reflected a lack of confidence from both customers and employees, ultimately resulting in mass redundancies. The key problems noted by the factory manager were as follows:

1. **Management / Leadership and Lack of Agility** - The management team had attempted to beat off competition through increasing plant volumes and producing

more of the same, in a market that was asking for quality, innovative products customised swiftly to its own specification. The management's inability to spot this and act quickly to redress the balance had eroded its market share and leadership position. The B-brand competition is always difficult to beat on the aspects of volume and throughput, and the management team possibly failed to recognise the strength of an Agile plant in the light of the changing competitive threat.

2. **Inflexible Workforce** - the various workforces at the Northern facility were represented by a number of trade unions with little understanding of the disruption that multiple negotiations around even the simplest decision caused. The unions could not be described as militant, but they strongly resisted change in a marketplace that relied on change, with fashion constantly demanding reduced product development life cycles and constant innovation. This was coupled to historical job demarcation and little acceptance of the need for multiple skills training on-site, to establish a workforce capable of performing a range of task as opposed to the established demarcation.
3. **Traditional Bonus Scheme** - the use of payment by results and a bonus scheme was responsible for hundreds of wage rates and widespread disparity between workers performing similar activities. This produced little team spirit and resulted in a total lack of trust between the management and workforce. "They pretended to pay us, and we pretended to work" was how one ex-worker described the management-workforce balance. Absenteeism could run as high as 14 per cent of the workforce at critical times in the manufacturing cycle.
4. **Outdated Manufacturing Processes** - the manufacturing process was based on traditional methods and planning processes, and resulted in large batch manufacture of questionable quality products to hold for stock. The supply base

was large, at over 450 first tier suppliers, fragmented, and suffered disruption from poor quality components. This was coupled to an outdated manufacturing strategy of large batch manufacturing practices and high product stock holding, just in case the orders came. This inevitably resulted in the wrong products being manufactured and held, leading to poor service levels and high inventory costs.

Case study B's base manufacturing strategy had not changed since the 1950s and a number of the key stakeholder groups did not accept or recognise the need to change. The staff and workforce found themselves solving repetitive problems, stuck in a revolving crisis emanating from established custom and practice on site. Prior to embracing change, the employees needed to recognise the need for change. The issue of ownership of change was to become one of the keys to the transformation, facilitating 1100 employees through the enlightenment of the facilities own "steps to world-class manufacture", which was noted by factory manager as "the most difficult job in his life, but also the most rewarding." The management team began with extensive benchmarking to define the current shape of World-Class Manufacture (WCM) and companies like B and D, IBM, ICL and Nissan helped to frame the current gap and future direction for them. They discovered a series of businesses that had stripped out waste by empowering the workforce, and which had invested in teamwork and stepped away from the existing model of the traditional British manufacturing business. The stark reality started to sink in as they considered the magnitude of the task ahead: to survive, they had to change the very basic systems, processes and assumptions upon which the business had been built over the last fifty years. The manufacturing Director took the first steps, with the development of the Manufacturing Policy Manual now running to its fifth issue. 'The Bible', as the

manufacturing manager refers to it, galvanised the thought process and set down the management objectives. The change management plan can be defined as follows:

- **Focus Upon the People** - striving to develop highly motivated teams of people across the entire business and aim to penetrate every function.
- **Pull Together** - focus the teams on a shared plant-wide goal and link the energy of each team to pull together.
- **Prepare the Ground for a Continuous Improvement Culture** - develop a flexible problem-solving environment and adopt basic problem-solving tools.
- **Empower the Teams** - enable every team to own the plant's various processes and problems.
- **Generate a Just Do It Culture** – commencing the change process and focus the energy of the business on change

Case study B encapsulated the program into the eleven steps towards World-Class Manufacture and charted a comprehensive plan towards the goal.

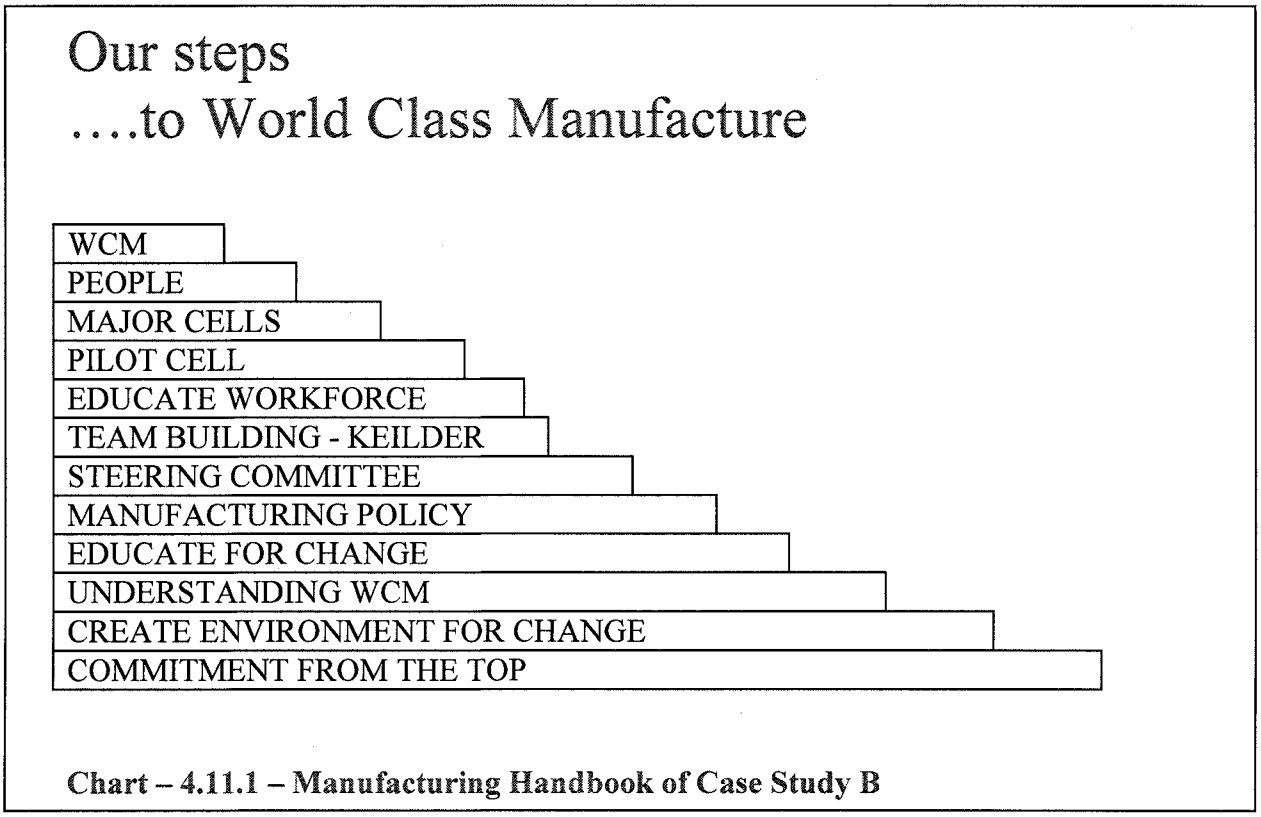


Chart – 4.11.1 – Manufacturing Handbook of Case Study B

Step 1: Commitment from the Top - the plant manager comments: "In the late 1980s the board of the parent group gave a strong message to the local management: 'Put it right'. The local management accepted this challenge." The Manufacturing Director commenced the definition of management characteristics required to accomplish the transformation. The vision of the initial program continued under his replacement, as he attempted to galvanise the full management team. He would bring a strong grip to cost control and the vision implementation process, harnessing the full potential of the management team to achieve the new common goal of the Northern facility in its quest become a world class facility.

Step 2: Create the Environment for Change - the development of an environment for change focused a significant amount of the team upon the following areas:

- **Consolidation of the Management Structure** - the creation of an environment that welcomed change proved to be one of the fundamental building blocks, according to the plant manager. The existing management structure was reduced from seven levels to four and first-line supervisors gained increased status, with the aim of increasing reaction speed, enhancing the sense of ownership and improving decision-making. The development of the first-line management team helped to establish the commencement of problem ownership and the willingness to pull as a team.
- **The Introduction of a Plant Wide Briefing Process** - the initial team briefing process training was conducted by the Industrial Society and a monthly two-way plant briefing process was introduced. This activity included a new level of financial information not previously shared with the workforce. This process initiated a sharing of knowledge and commenced the fostering of

ownership through the business; this activity reflected a significant step towards employee buy-in into the change process, with a number of the interviewed production operators commenting on the increased level of involvement that this activity generated within the workforce.

- **Focus upon Increased Productivity and Flexibility** - the elimination of demarcation and restrictive practices was to prove a difficult issue to resolve through the end of the 1980s, with a number of the management team commenting on the entrenched views of both sides through the early days of the change process. Many years of custom and practice had shaped the business and reluctance to change on the part of the unions made for long and difficult negotiations. The unions had deeply-held suspicions towards the motives of the management team and remembered well the adversarial relationship that had built up in the 1970s and 1980s by the mid 1990's, the bonus-related schemes were totally replaced by guaranteed wages. This gave the ideal opportunity to develop multi-skilling and increased job flexibility, giving cases B the ability to use skills across the site. The partnership between the management, employees and the union, founded upon the removal of the conflict of the 1980s, fostered the culture of change acceptance that would pave the way for the development of C.I. activity.
- **Remove the Focus upon the Inspection Function** - the lighting production at the facility had historically been based upon an "Inspection and Pass Off" process, reminiscent of mass production of the 1950s and 1960s, with little ownership from the production facility. The restructuring of this process allowed for a decentralisation of this "Pass Off" operation, focusing efforts by the team on production of products that are right first time and an increased

sense of ownership, immediately resulting in increased productivity and reduced quality costs with unit production and increased pass rates at the end of each production line. The breakthrough resulted in each team taking ownership for its own quality and production performance.

- **Trade Union Negotiations** - the management team identified the need to work more closely with a smaller number of shop stewards representing the workforce. As a result of discussions with the union representatives, this was reduced to nine delegates for the entire plant. The author feels that this activity combined with the newly introduced communication and briefing processes, helped form a new conduit between the management and shop floor, facilitating the C.I. activity by developing a strong voice for both parties. Significantly, many of the union representatives interviewed by the author became early converts to the transformation process and accepted the need for fundamental change. "The union then used the power of persuasion to bring along the shop floor", comments the Manufacturing Manager.

Step 3: Understanding World-Class Manufacture - to facilitate the learning process, the full management team embarked upon a benchmarking tour of B and D, ICL, IBM and Nissan. This activity highlighted the gap between case study B and other world-class manufacturing locations of the 1990s. The study tour was supported by in-depth workshop activity focusing on a number of hard techniques and skill based activities. "This approach was very different to some of the other Total Quality approaches around at the time", (Mortiboys and Oakland 1990) comments the key management change agent. The process selected reflected an approach that was migrating from TQM activity towards true Lean Production techniques, commencing

an understanding of work flow analysis, Just–in-Time component flow and a number of other basic Lean tools. The change management team commented that they recognised early in the process the need to win over more than just hearts and minds: they also needed to bridge the technical skills gap they had witnessed at the various case study facilities. The plant manager comments that they very quickly appreciated that the new Lean manufacturing approach required a fundamental re-education program across the entire facility.

Step 4: Educate For Change - The training process touched all key management, engineers and senior union officials and made many converts towards the new Lean production techniques. The author did interview a small number of disenfranchised operators, though considers they were in the minority of the employees interviewed. The key change agent considers the early converts as disciples within the production facility, powerfully disseminating the Lean message to the full workforce. He remembers the team-building and awareness sessions at Kielder (outdoor activity centre) as key breakthrough sessions, turning concepts such as cell structure deployment into reality and converting many of the doubters, with almost 1000 employees attending the conversion sessions.

Step 5: Manufacturing Policy - the development of a policy document upon which to base the improvement process formed a central thread to the manufacturing director's change master plan, and is considered by the management team as the "bible of change" within the facility. The development of this central operating policy document helped to galvanise the senior management team's commitment to the change and provided a "hand-rail" to guide management and a method by which

everyone could contribute to the change process. All areas of the production facility contributed to the construction of the policy document. The emotional buy-in was strengthened through the deployment of the manufacturing policy and the rollout process, converting many workers around the new banner of 'World Class Manufacturing'. Every employee, at every level, was allocated a copy of the latest level document, and the management team feel that at the time, this helped to cement awareness and ownership of the company's new goals, galvanising the entire workforce.

Step 6: Steering Committee - the change process was managed by an internal steering committee and the individual actions championed by a series of sub-teams, with the management structure, plant layout, space requirements, manning, cell development and family groupings all developing organically from this activity deployment process. The development of the strong steering committee, managed by the Manufacturing Director, brought significant strength to the change process and ensured that any roadblocks encountered were swiftly removed. The key change agent considers that this aspect of management guidance was essential to the penetration of the process.

Step 7: Team Building - the development of a strong team, committed to change, was recognised very early in the process by the site management team; it was identified from the study tours as a prerequisite if they were to make the changes required. The Keilder training sessions, cutting across all hierarchies and functional barriers, established a precedent of team building and management commitment, and at over £4000 per 25 people, gave a powerful message of total commitment to change

to the 950 employees completing the course through the 1990s.

Step 8: Educate the Workforce - the education process is considered by the management team to be ongoing, though the author has witnessed two significant phases of training. The first phase of activity initiated the development of the simple Lean tools and TQM philosophy of the 1990s. The second phase of intense training is currently underway and includes the systems and processes of Six Sigma. The initial training activity covered all levels of the business, with the actual training program covering a spectrum from strategic visioning through to basic lean system development and understanding. The subtle change of direction through the 1990s highlights a more cost-focused training plan, rolling out waste reduction and value analysis training. This reflects the step change from the TQM foundations of the 1980s to the acceptance of the tools and techniques of Lean Production.

Step 9: Pilot Cells - the initial cell production activity was piloted in the late 1980s and early 1990s for the manufacture of 'Discharge Gear' products, with responsibility for aspects such as quality being devolved to the cell manger and the cell operating team. The initial cells, demonstrating the benefits of cellular structures and reduced scrap by 99% and work in progress by 83%. The activity was coupled with major improvements in set-up times and productivity. The establishment of the initial pilot cells helped to convert a numbers of doubters in the facilities, providing proof of the possible gains available from the Lean techniques and methodology. The author interviewed a number of operators involved in the activity and concluded that even operators that had shown initial resistance to change and had taken a degree of time to accept the cell production, were unable to argue with the efficiency and quality

improvements.

Step 10: Major Cells - the success demonstrated in the pilot cell was extended into the rest of the facility, establishing a series of cellular production facilities located in family groups. This process aimed to generate the same level of flexibility throughout the business across all of the production employees. Quality responsibility was delegated to the operators, with direct product responsibility being held within the cell structure, and the author witnessed a high degree of autonomy on several occasions within the cells' operational remit. The author feels that the new autonomy gained from the cell structure has made a significant contribution towards the growth in the employee product ownership that is reflected in the cell structure. The strong ethos of ownership is subsequently reflected in the performance of each and every cell established throughout the manufacturing facility that has been studied in the course of the research. The cell structure has been discussed with a number of younger operators, and it is noteworthy that they are unable to visualise the flow production line assembly process previously employed by case study B. Culturally, the cell format is now well accepted as the norm, not the exception across the entire facility. The facility Manufacturing Manager comments that the employees now think in terms of cells and product ownership in contrast to production line demarcation.

Step 11: People - the development of facilities people is considered by a number of the managers as being one of the most rewarding aspects for those involved in the change process. The change management team feel they have worked very hard to move the total workforce forward in terms of commitment, time and money. Spending over £2,000,000 since 1992 and winning a National Training Award in the process.

The Manufacturing Director comments: "we understood well that with every pair of hands we got a free brain, so we decided to use it." The financial investment in the people has been significant and is ongoing in the current training and development activity on site coupling the people development with systems such as ISO 9000 (Anwar 1996) started the synthesis of commitment and process across the facility.

4.12 The Road Onwards From TQM to Lean

The development of case study B has been rapid and fundamentally driven by Lean Manufacturing process change through the 1990s, subsequently followed by a period of consolidation and then development of the tools and techniques of Six Sigma. The journey would see four Manufacturing Directors come and go and several change agents involved in taking case study B through the various levels of incremental improvement. The management commitment and financial investment continued through the late 1990s in the areas of high-tech capital equipment combined with the ongoing development of the manufacturing cell structure. Through the late 1990s, a number of the change agents considered the pace of a number of initiatives slowed down as case study B commenced a period of considered consolidation. The incumbent Manufacturing Director through this period, referred to this chapter of development as the business having a mild form of "initiative overload," an inevitable consequence of the magnitude of the transformation. He notes a number of areas that the facility focused upon in the short to medium term to ensure they steered through the difficult period, particularly acknowledging the following areas:

1. **The Development of Management Information Systems** – the key technology focus through the late 1990s was upon the actual day-to-day information process in the business, building upon the MRP information and delivering more concise daily

information to the workforce. The Manufacturing Director stated that the objective was "to manage the short-term aspects of the business with a higher degree of accuracy and in a more timely fashion, allowing MRP to actively drive the longer lead-time components of the business and add a short-term platform alongside". He recognised the need for the business to develop a more Agile manufacturing platform based on the solid foundations of Lean Production skills and.

2. **The Dissemination of Management Information across the Facility** - the objective, could be considered as aiming to deliver a simplistic understanding of the product and process requirements to the shop floor level in a language and format they are able to utilise in the day-to-day running of the business. The central aim of this activity was defined as reducing bureaucracy and increasing the business pace, taking the improved and more accurate data and ensuring that they were used by all levels, from the MD to the shop-floor operators.

3. **Continuous Employee Development** – case study B has continually attempted to lift the skill level of the facilities workforce to the next level of capability both on the shop floor and amongst the staff. The goal, as defined by the Manufacturing Director, is expressed as "delivering increased operator sophistication at every level of the business". Skills training and an additional review of the opportunities of dual skills complemented this activity across the entire business through the late 1990s and can still be considered as ongoing. The activity was based upon the management premise that case study B could make significant progress in terms of meeting the business objectives from the continued drive towards a more highly skilled workforce and dual skilled teams of employees across the entire factory. Rolling out the techniques of Lean Manufacturing and engraining them into every aspect of the business, with increasing focus on the synthesis approach of Lean Sigma, harnessing the

mathematical management skills and Six Sigma tools over the last two years.

4. **Continued Quality Development Program** – the Manufacturing Director considers the quality development program as one of the most significant challenges of the development process and one of the biggest development steps, converting the workforce to accept a broader definition of quality and breaking away from a slightly narrow product-focused understanding of the term. He fully understood that the A-brand quality performance of the plant needed to remain one of the key tools differentiating the facility from its low-cost Far Eastern competitors.

The new broader definition of quality focused heavily upon areas such as delivery service strike rate levels, product development cycle times and end customer satisfaction levels, measured by the development of a balanced score card approach. They aimed to encompass the entire scope of the business in a quality sense, not just the traditional "Pass or Fail" of the light fittings manufactured at the Northern site. In the author's view, the extension of the quality goals fitted hand-in-hand with the cellular structural development and increased understanding of the value stream throughout the manufacturing facility.

Through the course of the research activity case study B progressed through the period of consolidation and the management team actively commenced the next phase of the sites C.I. development. In interviews with the management team they consider that the second level of Lean Production training combined with the basic tools of Six Sigma significantly strengthened the progress made at the facility over recent years. The management team recognised that Lean initiatives such as Kaizen had stalled somewhat and hade made limited progress since the late 1990s. In reality the

manufacturing management team could be considered as consolidating efforts through to the end of 2003, without any considerable effort being applied to drive the more aggressive techniques such as Kaizen to fit the technique to the current business system. A number of interviewed members of staff commented that they had made great progress and that many of the gains from Lean had been introduced, even questioning on a visit to the facility in 2002 whether they needed to continue upon the Lean Production path. This would change dramatically at the beginning of 2004, as the senior management commenced a significant Lean Sigma drive across the facility.

Case study B significantly accelerated the pace of Continuous Improvement and change management in 2004 across the facility, with the employment of an experienced leader of change management projects from a local power tool manufacturer. The period of consolidation could be considered as over for the facility and acting as the catalyst a systematic change process commenced across the entire facility, touching all areas and functions. The new change agent initially conducted an operational skills assessment across the site and commenced the re-energising of the change management activity with a number of techniques he knew well from his previous operational manufacturing engineering and quality management experience. The activity would be steered by a small team of experienced practitioners recruited from a local Lean Sigma company implementing a proven system and introducing a series of tried and tested techniques. The latest phase in case study B's development was about to commence in stark contrast to members of the management teams views in 2002. The principle of the new program can be summarised in the key two threads:

1. **Aggressive re-launch of the Basic Lean tools** - with significant focus upon Breakthrough Kaizen and 5S workshop management activities.

2. **The Introduction of Six Sigma** – launching the initiative across the site and commencing the blending of the two techniques.

4.13 Phase 1. The Breakthrough Kaizen Kick Start Program

As the newly appointed Operations Director, the new change agent commenced the Lean Production "Kick Start Program" with the introduction of the 'Breakthrough Kaizen' initiative. Having had previous success in his use of the 'Breakthrough Kaizen' techniques he would lean significantly upon his implementation experience gained in the power tools industry and from his C.I. activities in brown goods manufacture. In discussions with the author, he indicated that in his view, the technique delivers the proven formula of a time-constrained, multi-functional Kaizen team delivering significant floor space, efficiency and quality improvements delivering tangible wins from the first activity. The Lean Production "Kick Start" program focused on the introduction of two specific techniques into two areas:

1. The introduction of pure time-constrained "Breakthrough Kaizen" activity on bottleneck manufacturing areas and high-focus problem manufacturing areas.

The use of the aggressive technique of "Breakthrough Kaizen" on a group of employees that were more used to the incremental approach to the introduction of L.P. techniques created a degree of initial uncertainty in the involved workforce. The author discussed the emotional reaction with a number of employees, who believed they had progressed from a state of:

- "This can never work"
- "It can not improve our area"
- "We have looked at this a thousand times"

With a distinct shift becoming evident through the activity to the new state of:

- "It's hard to believe the improvement in the area"
- "I could not believe we could make this much improvement"
- "It was a hectic week, but it works - you just got to do it"

The Breakthrough Kaizen activity resulted in significant floor space and efficiency improvements from the first roll-out team with the initial training week focusing upon a known problem area, generating significant results:

- **73% Floor Space Improvement – f**reeing up vital production space in a facility that was convinced it needed to invest capital to expand beyond the current footprint of the facility
- **40% Efficiency Improvement – i**ncreasing production by over 40% with the same workforce and no significant investment in tooling or machinery by harnessing the full power of Lean, workshop management, single piece flow. Load unload stations, Takt time analysis, and work balancing activity

Both of the results were achieved inside the first five working days of the initiative roll out plan. The Operations Director considered this quick win as an essential step in the initiative roll-out plan, contributing greatly to the successful acceptance of the initiative by the shop floor. The "just do it" attitude he had helped develop at previous facilities can be considered as becoming established at case study B through 2004 with the consistent successes of the Breakthrough Kaizen approach.

The process delivered an average of 52% floor space reduction and 25% efficiency improvements area by area through 2004 whilst targeting bottleneck and poorly performing problem areas of the production floor. The results should be considered in

the context of areas that had been addressed many times over the previous ten years. Quality performance on the manufacturing area can also be considered as improved with both the end of line pass rate improving and end of line quality being improved. Beyond the measurable results significant improvements to the production area could be witnessed through the course of the study and the author would highlight 5S introduction as a key element of this activity.

- **The Introduction of the Principles of the 5-S Workshop Management Techniques** – commenced in the injection moulding and plastic component preparation areas of the facility. A new area Manufacturing Manager, introduced the technique of 5-S workshop management to the moulding and plastic preparation areas and commented that, "the technique prepares the production area for the implementation of true Lean Manufacturing, sorting and shifting the essentials of the manufacturing area, cleaning, preparing and painting the defined areas to ensure we have established a solid foundation for Lean Manufacturing in the future."

The author witnessed the "before and after" appearance of the 5-S activity areas and would comment on a vast improvement in the use of space in the pilot areas. General tidiness was improved, with clearly designated space for all forms of material and a generally efficient appearance to the manufacturing area.

4.14 Phase 2. - The Launch of Six Sigma

The second phase of activity aimed to commence the development of the S.S. initiative on the manufacturing site, intending to combine the benefits of the initiative with the Lean production techniques that had been established. The Operations Director considered that the marrying of the two techniques had been successfully attempted at his previous facility and many valuable lessons had been picked up throughout the introduction process. In discussions with the Operations Director, it became clear that he felt the time was right to add the discipline and structure of S.S. to the well developed and widely known Lean system that case study B had established over the last ten years. The ten key aims of the blending of the two techniques are defined by the C.I. team at case study B as follows:

1. **To Rejuvenate the C. I. Program** - the management team recognised the need to re-start the C.I. initiatives and attempt to remove any complacency.
2. **To Add the Structure of the Six Sigma System** – bringing the structure to the established Lean methodology and enhancing the C.I. initiative on site.
3. **To Develop a Measurement Based Approach** - by commencing the development of a metrics-driven C.I. project through the use of SS measurement techniques and measurement system development.
4. **To Commence the Process of Mathematical Management** - to develop a more extensive statistics-based toolbox within the business to attack a number of process-based opportunities.
5. **To Establish a Company Wide Approach** - to spread the C.I. activity from the shop floor to the indirect departments via the use of S.S. in all areas of the business establishing a true company wide approach.

6. **Harnessing the Cost of Quality** - by commencing the Lean Sigma process with a Cost of Failure activity and helping to generate departmental ownership and acceptance of C.I. opportunities across the site.
7. **Developing a Target Driven Process** – via setting individual targets for each department and business team, linking all of the targets to the plant goal.
8. **Development of an Annual Review** – to review performance for each business team across the facility, establishing a project calendar with an annual cycle approach.
9. **Focusing upon all Areas of the Business** – aiming to establish the program at multiple levels with Design for S.S. and an indirect employee program eventually being commenced alongside the manufacturing activity.
10. **Individual Ownership** – aiming to make every individual in the business responsible for the C.I. initiative within an agreed company-wide plan

In terms of rejuvenating the Continuous Improvement program on site, case study B has historically had strong roots in the LP initiative, and in discussions with the author, the management team considered the time was right to spread the base of the C.I. program to maintain the momentum, commencing a process that is designed to simultaneously encompass the more technical areas of the operation via the statistical techniques of S.S. The key aims of the initiative very closely reflect the initial C.I. goals of the 1990s. The management team feels that the addition of the twelve-step methodology and structure of the S.S. system to the established Lean methodology in the manufacturing plant delivers an easily identifiable project template and delivery road map. With the belief that the initiative will commence the development of an agreed metrics-driven C.I. project deck filling a gap occasionally found in Lean-based C.I. projects (Harry and Schroeder 2000). The results will be available to be audited

via the use of S.S. measurement techniques and processes such as GR&R (the study of measurement repeatability and reproducibility) and financial audit tracking. The ability to move to a process of hard measures and financial project delivery is considered by the senior management team as an essential next step for the facility. The blending of L.P. and S.S. processes into a holistic L.S. improvement system has been considered for over twelve months by the management team and awareness sessions convinced the full team of the applicability of L.S. as the next step in a long training road that case study B has supported for over ten years. The stated aim of the Operations Director is to use L.S. to aid the entire trained workforce via the development of the more extensive statistics-based toolbox that will complement the L.P. training legacy and make a pronounced impact on an untouched area of opportunity. The techniques of S.S. will be used throughout the business to attack a number of process-based opportunities identified at the Cost of Failure stage that may have proved difficult within the limitations of the L.P. toolbox in isolation.

The change management team feel that the time is now right to commence the process of spreading the C.I. activity from the stronghold of the manufacturing leaders and technical teams on the production shop floor. Spreading the initiative to the previously isolated and lightly involved indirect departments that historically had very little involvement or impact in the C.I. process via the use of SS in all areas of the business. The deployment of the transactional training (Six Sigma methodology and training for indirect functions) methodology as a secondary wave of S.S. training aims to tie this previously untapped area into the C.I. initiative, the rollout process being founded on the deployment of the Cost of Failure assessment activity to all areas of the facility. The CoF process aims to aid the S.S. rollout via the generation of a strong buy-in and

acceptance from all areas to the newly exposed C.I. opportunities highlighted across the full breadth of design and manufacturing on the site. Individually agreed targets will be set for each department and business team, which have been accepted by each team as feasible and indeed have been uncovered by the employees from each business team or manufacturing area. The agreed targets will contribute towards the development of an annual metrics-based review process for each business team, based on the findings of the original 2005 Cost of Failure process.

The plant-wide CoF initiative will be used to establish the C.I. program at multiple levels throughout the site, with the introduction of Design for S.S. alongside the transactional, indirect employee program that will commence in a second phase, parallel to the manufacturing activity, thus targeting all levels of product interface and all value streams on the site. The aim is to make every individual in the business responsible for the portion of the C.I. initiative they contribute towards, within an agreed company-wide plan. Individuals will thus be focused upon the declared opportunity to contribute to the plant-wide target via delivery of the individuals' own annual targets, specifically aligned to the workplace and tasks of each individual employee. The introduction of the Cost of Failure initiative has been promoted by the Operations Director to ensure that a strong company-wide acceptance is driven from the financial definitions of possible financial opportunities in each area of the business. This will tie the full workforce into the goals of the facility and highlight the individual contributions to the 2005 business goals that are required from every employee.

Following discussion with the Six Sigma introduction team and the senior management team, the rollout strategy favoured by the senior management can be

considered as a well thought-out development and extension of the case study A rollout experiences gained over a four year S.S. introduction process on the manufacturing site of the nearby case study A site, coupled with a significant degree of hard-won tribal knowledge transferring sites to aid the introduction activity. The development path for the activity will be considerably eased by a number of developments and learning's. Based on discussions with the cases study management team, the most significant aspects of the activity can be summarised as follows:

- **The Broad Understanding of the Size and Shape** - of the introduction and rollout plan and the knowledge gained from the case study A activity. Many similarities can be drawn from the two sites; they share a very similar workforce profile and demographic background, with both facilities having similar histories of industrial development.
- **Senior Management Experience** - of a successful introduction project, having been through the process in case study A and other rollout programs, and significantly a number of key players in the Case study A introduction have moved to the management team of case study B and will actively participate in the introduction process.
- **The Availability of Skilled Trainers and Experienced Practitioners** – the "been and done it" team are now well experienced in the identification of roadblocks and the appropriate techniques available to remove the issues they may face in case study B.
- **The Availability of Commercial Training Material** - Specifically tailored training programs have improved significantly in the last ten years, with proven software such as Minitab and project tracking programs now widely available.

- **Top Down Initiative** - acceptance of the need for the senior management team to lead from the front is now well understood from case studies and academic research projects that are now in the public domain.
- **Well Prepared and Fertile Ground** - significant experience of other C.I. initiatives and an established Lean culture across the business will smooth the introduction process and ensure that most employees are introduced to the program from a background of C.I. activity.
- **Tool Awareness** - the experiences of the Lean C.I. tools and the introduction of the rigour and discipline of S.S. will allow case study B to push ahead with the established L.P. tools, strengthened by the project management techniques of S.S. reaping fresh rewards from established techniques.
- **Leading a Local Approach** – case study B will benefit from reduced pressure to conform to a rigid global model and could develop a significantly more local approach with a greater degree of autonomy over the program. Case study A occasionally suffered from the over-rigid control of the process by an American central control committee.
- **Competitive Crisis** – case study B has significant competitive internal and external pressure that will serve to focus the entire workforce upon the need for the initiative, removing the option of the do nothing strategy.

The ability to follow an existing path and improve or develop a proven road map is considered by the management team as an excellent opportunity to learn from the successes and failures of the Northern site. For the management team, the opportunities to accelerate the rollout process, benefiting from the knowledge gained from the experiences of case study A and others will potentially halve the rollout duration. The author feels that all areas of the development activity can be

commenced with confidence, armed with full knowledge of the main issues they are likely to encounter and a catalogue of tools and techniques that have successfully delivered results at case study A.

The one significant thread discussed for the future with the management team at case study B covers supply chain systems development and the internet in line with the thoughts of Lancioni, Smith, and Oliva, (2001) and Latamore and Berton (2001), Hornyak, and Ostrander (2001) and Greengard (2001) Bowman, R. J. (2001) with one significant contact considering this activity a great fit with the L.S. development program at case study B and an excellent opportunity to globalise the two way supply network of case study B. The management at the facility fully understands the size of the step required taking them towards e-business and it is firmly on the development agenda.

4.15 Migration Path

The migration path of case study B can be considered as less of an evolutionary process than case study A and more a series of individual steps with the facility still traveling the path from T.Q.M. to Lean Sigma. The journey of case study B can be considered as a more pronounced 'stop, start' approach than case A, lacking a linear flow. The journey undertaken by case study A can be considered as one with a number of individual initiative ideas, forming in the minds of management, being introduced, rolled out and ran for a period of time prior to the acceptance of the need to continue the C.I. evolution. The progressive building block path to L.S. is not as

evident as in case study A and reflects a local approach to the introduction of C.I. methodologies. The migration path summary can be defined as follows:

- **Mass Production** – the northern site of case study B was established as a mass production operation with small variation in the lighting production manufactured on site, with a small catalogue of lighting products manufactured in high volumes. The move to site the design centre at the facility in the late eighties increased the offering of bespoke designed products and commenced the move away from mass production. The facility still produces a line in high volume strip lighting for low cost fluorescent tube applications. The line runs continually with limited variation and remains as the only mass production applications on site.
- **The Development of T.Q.M. at the Facility** – following on a similar theme to case study A the manufacturing facility commenced a basic T.Q.M. roll out initiative with a number of simple Lean Principles. The activity formed quality circles in the late eighties and developed concepts such as cell production as an extension of the T.Q.M. drive on site. In discussion with employees the researcher discovered that the move was considered a major step at the time, with activity to generate a single tier workforce and introduce multi skilled operators and technicians into a very rigidly structured unionised facility. The introduction at case study A had been much more evolutionary and without the influence of the union the work force had historically been multi skilled.
- **The push for Lean Production** – the introduction of the tools of Lean Production commenced in the T.Q.M. phase at case study B in the manufacturing and assembly areas with a roll out of manufacturing

initiatives in the early nineties. The management and supervisory structure being impacted by the development of cell based work units in the mid nineties with profitability being pushed to the individual cell leaders. The Lean Production roll out process would then remain relatively static for a number of years until 2002 / 2003. The introduction of the breakthrough Kaizen activity commenced the process of kick starting the L.P. drive in 2004, focused on the drive towards waste reduction and output efficiency and employing the breakthrough techniques of case study A and D.

- **Agile Methods** – case study B accept the need to promote the theme of Agility and focused effort on the development of management information systems to promote Agility in the late nineties. The market remains one that makes for stock and sells from stock at most price categories with a degree of top end bespoke lighting designed and manufactured for civil engineering projects. The civil projects tending to be based around generous time scales with the lighting rarely on the critical path of the project.
- **The Introduction of the Six Sigma Methodology** – the intent to promote Six Sigma across the facility is a current initiative at case study B, commencing the focus in the manufacturing assembly areas in 2006 and spreading plant wide through the course of 2007. The training material and roll out will follow the tradition 12 step process as they look to establish a 'foot hold' in the assembly facility, prior to expanding site wide.
- **Lean Sigma** – the facility consider employing the Lean Sigma initiative as a next step after the successful launch of S.S.

4.16 Case Study C

The author considers that the pharmaceutical facility based in Northern England fulfils many of the requirements to contribute to the longitudinal qualitative assessment. The key criteria identified are:

- **Continuity** - the possibility of regular interaction with the early identified key respondents throughout the research and general access to the change management team over the length of the case study.
- **C.I. History on Site** – case study C has a history of continuous improvement initiatives on the site studied and fully recognises the need to pursue C.I. activity.
- **Progressive Attitude** – case study C has in place a progressive and open-minded management team in significant positions.
- **Progressive Approach** – they are an organisation that is open to change and historically one of the most progressive of pharmaceutical manufacturers.
- **Field Leader** – the global company is a Blue Chip business, leading the market in its own field in a number of market segments.
- **The Challenges to the Northern Facility** – the case study site can be considered as a business facing notable challenges and competitive pressure from both internal and external threats.
- **Bringing a Different Industrial Perspective** - the business is reflective of an individual market segment, representing the UK pharmaceutical industry.

The author has historical links with the site, developed over the last ten years, and has gained good access to many areas of the manufacturing business and also to several of the key members of the management team. The author has taken a positivist stance in

the research in contrast to the action research activity of case study A. observing the change process in the facility and recording the process of change implementation on-site over recent years. The author would note at this stage that the very nature of the pharmaceutical manufacturing process limits the potential for interview and interaction with the shop floor operators and the very nature of the sealed manufacturing environment restricts the ability to interact with shop floor operators whilst they are fully suited up and operating inside a clean-room environment. The author conducted a large proportion of the interviews outside of the working environment to establish a degree of operator review in the case study, whilst respecting the restrictions imposed by the manufacturing practices on site. This should be noted as a different approach to the relationships established with the shop floor operators in the other case studies. The case C interviews were conducted with individuals outside the production facility after the production day, as opposed to workplace discussions with an operator and a group of peers.

Key members of the change management team have granted access to the author over the period of the study, exposing a number of the fundamental elements of the change process in the facility through the course of the study. One of the key change agents involved in the case study took early retirement from the business in 2003 and as such was unable to contribute to the concluding stages of the case study activity as a participant. The site has a recent history of increasing Continuous Improvement and change management and has strategically focused over the last 5 years on staying ahead of the external competition. More importantly, in the author's opinion, case C has focused on the internal elements of competition, in line with an increasingly competitive internal scenario.

4.17 The Global Company

Case C is a leading global manufacturer of pharmaceuticals in a number of key areas and holds many patents and product protection registrations. The northern facility has historically developed its product range from penicillin production in the 1940s and 1950s to today's complex mix of various finished medical treatments. The global business has historically been focused around the design and development of new medical treatments, with limited external pressure in a rapidly expanding market. In the author's opinion, this has changed significantly within the last five years, in response to increasing competitive pressure from the global lapsing of patents and within the European manufacturing centres, internal manufacturing competition from low-cost manufacturing locations.

In discussions with the management team at case C, there is a general view that established products out of patent are being pressured by derivative products from mainstream A-brand competitors. The management team concedes that the recent competition to the site is increasingly internal. The development of a "strategic master plan", with internal plants pitching for business, has significantly changed the game for the facility, with increasing pressure on cost and efficiency from other facilities in Europe. With over 100,000 employees worldwide and historically 108 manufacturing sites in 41 countries, reducing to 80 facilities with the implementation of the strategic master plan in the last four years, the business is the second largest pharmaceutical company in the world. It experienced a £20.3 billion turnover in 2004 and £6 billion pre-tax profit. The global business is based around 84% pharmaceutical sales and 16% consumer health care sales. The consumer health care products became established in

the business portfolio as a function of the recent merger activity over the last four years; they are not a core element of the product mix, in the author's opinion, and will probably remain as an opportunistic element of the product mix of case C.

The research and development pipeline may be regarded as the life-blood of the business, and the declared clinical pipeline holds 140 projects, as declared in the 2004 annual report. Every individual interviewed on site at case C understands that the business lives or dies by the development of new treatments in the medium and long term. They use the established pharmaceutical practice of dividing the manufacture of general pharmaceuticals into two distinct phases, and the understanding of the two phases helps to explain the manufacturing framework of case C.

- **Phase 1 – The Development and Manufacture of the Therapeutic Materials** - the manufacturing process commences with the production of primary therapeutic materials and chemicals. The fundamental process in the manufacture of all medicines commences with the design and development of a therapeutic "active" ingredient that will become the core constituent of a pharmaceutical treatment. This primary material is then developed and manufactured to a specific, pre-selected and possibly patented formulation. They then develop the manufacturing processes and equipment required for volume production of active compounds and commences production of the active therapeutic material at designated primary manufacturing sites.
- **Phase 2 – The Conversion to a Marketable Pharmaceutical Product** - the second phase of manufacture is the conversion of the active primary compounds into a finished dosage formulation, packaged to deliver to the end customer. This phase is the responsibility of the secondary manufacturing sites

in the network, case study C is an example of such a secondary manufacturing site, with its prime goals being the conversion and packing of the active ingredients into the established pharmaceutical product. All appropriate quality checks and assessments are completed by the facility prior to shipment to the global distribution network for delivery to a worldwide market.

After completing a series of significant mergers the manufacturing arm of case study C now forms a global network of 108 sites in 41 countries, employing over 39,000 people in its manufacturing structure. The strategic master plan team focused upon the many synergies of the businesses, in an effort to reduce duplication and increase economies of scale. This focus upon the global strategic master plan resulted in the closure of 28 manufacturing facilities in the four years to 2004. To focus the mind upon the magnitude of the manufacturing facilities, they produced 5,900 tonnes of bulk actives for conversion in secondary manufacturing locations in 2004. This was then transformed into over 3.8 billion individual packs, which were packaged and delivered for sale in 138 countries. In discussions with the management team at the case study facility it is evident that the very lifeblood of the business and the entire pharmaceutical industry is the research and development of new drugs and medications. The pipeline remains full of new developments and they have consistently managed approximately 1,800 new product launches a year.

4.18 Strategic Master Plan

The Strategic Master Plan (SMP) can be considered as the long-term strategic manufacturing development program, bringing a degree of synthesis to the combined

complex manufacturing networks of the merger partners (Hilton 2003). The initiative is aimed at delivering an integrated change management methodology to enhance case study C's competitiveness and productivity across the spectrum of the existing manufacturing sites whilst reducing duplication within the manufacturing facilities. The VP of manufacturing announced the framework and outline principles of the SMP initiative in October 1999, and it remains the spearhead of case study C's manufacturing development initiatives. The initiative can be considered as being based around three core areas and interdependent development initiatives:

- **The Development of Manufacturing Excellence** – aimed at all of the global sites in the manufacturing network and establishing a process of measurement and development activity across the manufacturing network that establishes the concept of Lean Sigma in all manufacturing areas.
- **The Active Process of Network and Process Rationalisation** – focused across all sites around the globe and the related development of the manufacturing and logistic processes. Streamlining the manufacturing network to remove duplication and ensuring leverage of all manufacturing facilities.
- **The Development and Practice of Procurement Excellence** - applied across the whole network at all of its manufacturing and supply locations, removing duplication and consolidating the global spend to realise the potential economies of scale.

Following discussions with the northern management team, the author is of the opinion that the core element of the C.I. program is the introduction, development and use of Lean Sigma tools and techniques to challenge the established custom and practice and the current ways of working. The L.S. development led to forecast

significant global financial benefits, principally delivering improvements in areas such as reduced cycle times, increased productivity and improved delivery performance. Global financial improvements are difficult to pin down to purely LS projects, as the scale of the manufacturing rationalisation and purchasing economies of scale swamp the total improvements realised from the SMP. It is noteworthy that the 2004 annual report makes no reference to the technique of Lean Sigma, and indeed refers to efficiency improvements at over 80 manufacturing locations as a result of the use of Lean manufacturing techniques to drive improvements in process yields, improved quality and process simplification. The report continues to reference procurement excellence driving the low-cost supply chain, e-procurement and electronic auctions, initiatives that link back into the strategic master plan.

4.19 The Global Supply Initiative

The author recognises that the Global Supply Initiative (GSI) was the forerunner of the Strategic Master Plan in case study C. The four-year GSI program was announced to the manufacturing and logistics teams in February 1999 and aimed to restructure the supply network to align manufacturing strategy with the current business needs following the merger of two European businesses. The activity aimed to deliver economies of scale and structural benefits through network rationalisation of the two businesses and commenced significant purchasing initiatives to strip down the dual supply base. The initiative commenced the streamlining of the business and removed a significant amount of duplicate resources from the two merged businesses, paving the way for the introduction of Lean Sigma (LS) to the manufacturing business through the establishment, acceptance and implementation of the Strategic Master

Plan. In May 2000, the business launched Lean Sigma into the manufacturing base at its secondary manufacturing site (Case Study C). The rollout process would prove to be the biggest initiative the site had ever undertaken. The local management and implementation team understood that the initiative was introduced under the leadership of the new global manufacturing leader; a West Point trained military man heading up his vision of the future state of the business. The global manufacturing initiative that would become known as the "Strategic Master Plan" was to be introduced to the site in its prescriptive form, with a rigid implementation rulebook.

4.20 The Case Study Site

The site can be considered as developing a new manufacturing attitude through the 1990s, adopting the principles of TQM as the foundation of the C.I. activity on site. The manufacturing site expanded to cover over 60 acres, with more than two thirds of the output being exported, the United States being the largest market for the site's pharmaceuticals. The early TQM introduction activity was founded upon:

- **Project Management Focus** – via the introduction of a task force project management strategy to roll out and introduce significant C.I. activities.
- **Communication Activity** – including the rollout of "cascade" team briefings across the entire workforce in the early 1990s to ensure consistency of message to all areas and levels of the business.
- **Consistency in the Communication Approach** – through the introduction of a regular briefing calendar to maximise the impact of the cascade briefings.

- **Empowered Teams** - workforce empowerment activity and employee involvement processes, designed to ensure that all members of the workforce have the opportunity to actively contribute to the C.I. process on site.

The facility can be considered as following three distinct manufacturing and C.I. themes over the last fifteen years, with a degree of evolutionary development evident between phases one and two. The three phases can be summarised and explained as follows:

- **TQM (Total Quality Management) Development** - the manufacturing site adopted many of the core elements of the TQM methodology through the 1990s, with significant focus upon the soft side of the business, focusing around a people-centred improvement process. This form of TQM activity fitted in well with the caring family and community focused environment at the facility and the limited need to pay attention to the waste and efficiency line in the manufacturing side of the business in the 1990s. The TQM activity viewed on a number of site visits in the 1990s highlighted a majority of projects aimed at job enrichment and worker satisfaction, with few links back to the financial benefits delivered. Later projects of this nature aimed to tie back to a metric such as absenteeism or reduced accidents on site, and can be considered as being more focused upon the business needs whilst maintaining the healthy employee relationships built up historically.
- **The Lean Adoption Process** - the facility adopted a number of the tools and techniques of Lean Manufacture in the late 1990s and commenced a conscious process to add a number of the core skills of Lean onto the TQM framework that had been long established on the site. In the author's opinion,

the focus remained upon the soft side of the improvement spectrum, with little effort focused towards dramatically improving efficiency and reducing manpower in the manufacturing areas. The harder business issues such as labour reduction were considered as unpalatable to the workforce upon the author's first two site visits in the 1990s. This attitude can be considered as reflecting the strong internally focused position of the Northern site at the time and the degree of complacency that can come from being a showcase manufacturing location with a thriving order book.

- **The Strategic Master Plan (SMP)** - the SMP initiated the introduction of the Lean Sigma approach to the facility with the true globalisation of the corporate approach to C.I. with a prescriptive training and rollout approach. The Lean Sigma activity sat alongside a substantial manufacturing network rationalisation and created considerable changes to working practice across the entire site. In the author's opinion, this introduced a harder-edged approach to C.I. activity and radically changed the facilities approach to C.I. The softer people-based improvement aspect is still strongly featured in the C.I. activities of Lean Sigma, although the new L.S. process actively features a strong element of cost and benefit analysis in a harder approach to value-stream improvement. A shift has been witnessed in the activity and focus of C.I. towards a metrics-driven model with greater accountability for waste and efficiency measurement alongside the quality and service level strike-rate measurement.

Case study C offers a good example of the softer side of improvement projects being driven by the L.S. teams. The facility implemented an ergonomics improvement team

that delivered 80 workforce health and safety improvement projects between 2002 and 2004. The activity drove the hazard reporting up 60%, whilst the site recorded a continuous run of 3.4 million operator hours of production without a reportable accident in 2003. The initiative has been considered a significant success, and from 2004, it is being rolled across the global manufacturing network.

The project was steered by a multifunctional team consisting of 13 employees from differing areas, and was created with the aim of reducing accidents or repetitive strain injuries across the full site. The projects were funded by the site and one project authorised the procurement of a fleet of more comfortable, user-friendly forklift trucks at a cost of £347,000. The author has not witnessed similar expenditure without a definable payback across any of the other case studies. The facility actively pursued projects external to the site that could be considered as impacting the biodiversity of the flora and fauna of the surrounding countryside, though contributing little to the plant efficiency performance. In the author's opinion, this activity reflects the social conscience of company and the cash-rich nature of the pharmaceutical industry. They reported the activity internally as follows:

> "In Summer of 2002, the northern site and a local District Council, sponsored a survey of 67km of roadside verges across the North Pennines Area of Outstanding Natural Beauty to identify verges that contained diverse flora and could be improved if better managed. In November of 2002, the employees accepted a challenge from the North East Biodiversity Forum to help protect and develop the flora of three roadside verges in the upper dales. The challenge was met by a team of nine

employees who worked to cut brambles, coppice ash and remove cuttings to give rare plants, like the Lady's Mantle, room to grow."

This form of environmental, community-based project highlights the softer side of site and is in sharp contrast to the author's experiences at case study A. The pharmaceutical industry in general reflects a more environmentally friendly approach to the community and the employee base, and case study C has historically displayed this soft side at the facility.

4.21 The Structure of the Lean Sigma Team

The Lean Sigma structure on the site follows the traditional terminology and structure of S.S. with the addition of a corporate level of internal consultants mentoring and training the Black Belts and Master Black Belts. The accepted company terminology can be summarised as follows:

- **Advocate** – a production operative who has been through a basic four-day awareness program and understands the direction and structure of the Lean Sigma rollout process. Any project activity will be part-time and will probably involve around four hours per week, based around a simple core of basic L.S. skills with guidance from the area's Black Belt. They work on local tactical projects that are considered low benefit and low impact.
- **Green Belt** – an individual who has completed a ten-day training course on the tools and techniques and has worked on L.S. projects part time. The project activity will be part-time and supervised by the area Black Belt, although a broader spectrum of the tools and techniques may be called into

use by the Green Belt. They aim to complete at least one project in the first three months after completing the training program and focus for up to ten hours per week on projects integrated into the current role they fulfil.

- **Black Belt** – an internal expert fully trained on the tools and techniques and working full-time on L.S. projects and activities. The Black Belt will be assigned to an area or individual function and will lead the activity for that area of the facility. The workload will be full-time on L.S. projects in the defined area of responsibility.
- **Master Black Belt** – as a Black Belt, but with slightly higher degree of competence, a higher training workload and a greater degree of mentoring activity for the designated production area they are responsible for. The actual grade of the MBB is equivalent to a business unit head or operations manager.
- **Internal Consultant or Expert** – highly competent individual trained in the tools and techniques of L.S. with a significant training and mentoring role on the site. The internal consultant also has a reporting link to the corporate rollout team to ensure that the strict rollout process is adhered to across the site and that all corporate guidelines are observed.
- **Senior Internal Consultant or Senior Expert** – as the internal consultant, but with additional leadership responsibilities. The two consultants also function as the overall owners of the project hopper and the reporting cycle, interfacing with other sites to share best practice
- **Champion** – the leader of the L.S. initiative on site with responsibility for the success or failure of the rollout plan. The champion sits alongside the steering committee and positively influences the direction and velocity of the project.

- **Steering Committee** – a selection of the senior management on site with overall responsibility for the direction and prioritisation of the projects.

The Black Belt and Master Black Belt team consists of nine full-time individuals embedded within the business areas with focused responsibility for pre-defined elements of the facility. The manufacturing areas are defined as three core areas with two BBs/MBBs in each area. Site operations and Quality Assurance are allocated one each and the remaining BB is based in the logistics function. They have direct reporting lines to the functional head and a dotted line responsibility to the L.S. Champion on site. The team is currently supported by two core accredited L.S. experts, and a third L.S. expert is in the process of being trained up in all of the tools and techniques required to successfully perform and contribute towards the goals of the business in this plant wide, floating position. This team has a hard reporting line into the site L.S. Champion with dotted line responsibility dependent upon the individual projects they are supporting. The internal steering committee can be considered as integral to the successful rollout of the initiative and its acceptance across the facility. The program has been established with a representative plant-wide steering committee, with membership drawn from all areas of the senior management team on site focused upon supporting a structured monthly decision-making process that reviews the following areas:

- **Current Project Ideas Review** – considering the new project deck and the project hopper currently in place for the facility.
- **Clearing the Way** – discussing exception reports provided by the project sponsors highlighting roadblocks or issues that need quick resolutions.

- **The Manpower Requirements** – reviewing the current resource requirements and any decisions required to move resources across the live project deck.
- **Updating the Plant Priorities** – studying the options available to stop projects or start new projects after consideration of the business needs.
- **Considering the Cash Delivered** – reviewing the monthly financial performance report highlighting the financial aspect of project completion.

One Master Black Belt interviewed feels that firm adherence to the monthly cycle is essential in the foundation period, as it helps develop the routine of reviewing project timing plans, revising the project hopper and discussing support structures in preparation for the monthly meeting schedule.

4.22 Project Identification and Selection

The case study site reviews a number of threads in the process of selecting and identifying the key projects that will influence the priorities of the business. The threads have the primary aim of bringing together an information stream from many areas that provides quantifiable data, a considered metric and an estimate of financial benefit. The key threads of information can be considered as follows:

- **On Site Baseline Events** – measuring performance against standards, expectations or estimates to define areas and opportunities for improvement.
- **Focusing on Known Issues** – commencing with known problems on site that are considered to be hardy perennials or constant repeaters.

- **Benchmarking Activity** – focused activity conducted around other blue chip companies inside and outside of the pharmaceutical industry to expose the "best in class" performance levels required to become world class.
- **Other non-LS Projects** – retaining the knowledge of historical project activity that has identified additional areas of benefit or other improvements that are available to the manufacturing location.
- **Key Point Indicators (KPIs)** – the ongoing measurement of the critical-to-quality manufacturing measures to define any slippage or additional opportunities on the most significant measures in the business.
- **Regulatory Compliance Findings** – any findings of non-compliance or changes in the rules of operation from a compliance standpoint.
- **Technology Changes** – movement in the technology of the pharmaceutical industry or the support industries that support the facility.
- **The Workplace Improvement Roadmap** – any projects that contribute or assist the plant in progress along the road to better workplace management.

The information feed process is developed into a project priority matrix and is then compared to the business goal tree to define various levels of project priority, with the steering committee then deciding on the go / no go activity and assigning priorities to the project hopper. The accepted projects are transferred to a "Short Form Charter" - a document that acts as the project contract between the project sponsor, project leader and the business. The contract holds the following information:

- **The unique project tracking number.**
- **The project description and the process to be worked upon.**
- **The definition of the problem that requires a solution.**
- **The measurement that will be used through the project.**

- **The financial benefits translated into financial terms.**
- **Any business positive not reflecting a financial improvement.**
- **The potential or actual project sponsor.**
- **The potential or actual project leader.**

4.23 Black Belt and Master Black Belt Certification Process

The corporate teams use a process of placing internal consultants in individual plants alongside the plant steering committee to certify both the Black Belt and the Master Black Belt process. They approach the criteria slightly differently to a number of other S.S. businesses and monitor a broader spread of skills than other members of the case study research. They are focused on nine core competencies, only two of which are based around the individual skills of L.S. Case study A focus heavily on the ability to implement and train the L.S. skills. The case C areas of competence are as follows:-

- **The application and understanding of the fundamental Lean Manufacturing based skill set.**
- **The application and understanding of the S.S. project management methodology and skills.**
- **General business knowledge.**
- **The ability to teach and coach others in the L.S. skills.**
- **The ability to function as a mentor to others.**
- **The successful implementation of L.S. projects including good practice in general project management.**
- **General facilitation skills.**

- **The ability to drive change, acting as a key change agent and catalyst in the change process.**
- **General leadership skills.**

To be accredited the Black Belt is required to be highly competent in three areas and competent in six of the remaining. The Master Black Belt requires a high degree of competence in six areas and to be competent in the remaining three, and practitioners at both levels must be highly competent in both the Lean Skills and the S.S. skills base. The recognition process can follow two directions. The first is a thank-you card, known as the Bravo card, which is an informal, personal thank-you from work colleagues. The second is a formal award that looks at four areas of the business:

- **Passion and Urgency**
- **Innovation and Entrepreneurship**
- **Performance and Improvement**
- **Lean Sigma**

The various levels of recognition follow a pyramid approach related to impact.

- **The Manufacturing Roll of Honour** – this would typically reflect an impact across the manufacturing corporation.
- **The Regional Award** – recognising levels of impact across a geographical region or an individual function.
- **Site Wide Award** – a level of performance that is recognised across the entire manufacturing site.
- **Immediate Work Area** – rewarding an individual for a significant contribution across a work area.

The Lean Sigma award process looks to collect the best projects from the global manufacturing sites and share best practice whilst recognising the achievement of

both individuals and L.S. teams. The assessment is performed by a trained global team, measuring improvements along true L.S. lines. The results of the measurement process are published globally with the aim of sharing success and best practice.

4.24 Knowledge Management

Case study C are actively attempting to share the L.S. knowledge through the entire manufacturing business group, and they have developed a number of tools to promote both the spread of "smart" thinking across the global network and the retention of the knowledge in a fast paced, progressive business in line with the thoughts of Young (2003). They are promoting the use of electronic media to act as the key information repository and pushing three key receptacles, which focus on the individual, the project and the company-wide activity of L.S. as follows:

- **People Connect** - the individual practitioner is focused upon by the use of a rolling individual database designed to track the skills and experiences of every L.S. expert, making the skills available to any individual to question and ask for advice. The key threads reviewed can be considered as the individual's project and professional history, with special focus upon areas of significant knowledge, all the pertinent contact information and the languages the individual is able to communicate in. This is supported by a log of L.S. questions the individual has asked, replied to or is currently working upon.
- **Live Link: Project Workspace** - Case Study C monitor and advance the project activity of the L.S. program on a project database, powered by 'Livelink' software, to ensure an up-to-date global system that monitors project progress and provides basic activity blueprints, education and training

material, allows L.S. communities to share information and holds historical project activity for all divisions. The project repository is able to search and filter project activity by function, latest update, and title and to provide a pareto of projects in an individual area, allowing the activity to be tracked by area, facility, division and as a company. The author has witnessed a similar project-tracking tool at Case study A and considers that it is a significant advantage in a global company to retain the project benefits and learning's inside the company and also to focus the experts upon the target of delivering tangible bottom-line benefits to the business. The blueprint repository holds basic project outlines and guidance for experts working in such areas as L.S. quality improvement, L.S. lab design and running practices and energy management project activity. The training material and program are available alongside the training waves, training team information and the training community meeting place. The L.S. communities section bonds the individual communities that are currently focusing on an individual area and focuses upon the groups currently "Base lining" areas or value streams, teams working on SMED-based change-over time reduction, Kaizen teams, Kanban teams, LS laboratory activities and Lean-based documentation.

- **Electronic Communications Notice Board** - the electronic communication board attempts to highlight and focus the C.I. team upon the goal of "Operational Excellence" with the mission statement as a central element:

"We aim to build 'Operational Excellence' into the main artery of our Manufacturing Systems, creating a burning ambition to do things simpler, smarter, quicker and in a robust, reproducible way."

The communication forum also records the financial benefits of the C.I. program, year to date and against the annual plan, and holds all key presentations delivered internally and externally, a tools repository, a directory of the champions of the process and an up-to-date news board. The three tiers help to communicate to the global business whilst maintaining a local level of communication and a feasible local support structure. The approach is thorough and methodical and extends the L.S. community from a local level to a global program. This reflects the global approach evident at the northern manufacturing site in the development of the training material, information dissemination and standard rollout program across the manufacturing network of the business.

The Lean Sigma element of the strategic master plan has introduced a highly structured and formal process across the manufacturing locations of the case study manufacturing systems business. The commitment from the highest levels of the business is evident, and the rollout process goes as far as inserting corporate employees into the individual locations to remove road-blocks and to ensure that the corporate plan is followed with the minimum of local manipulation. Any down-side recognised through the tightly controlled process is more than compensated by the excellent training, training material, electronic support media and management commitment. Case study C has fundamentally reconsidered the needs of a global rollout of such a C.I. initiative and invested appropriately in people, materials and time to ensure that the rollout will be successful. The author recognises that case study C commenced the L.S. process after studying the successes and failures of Motorola, GE, ABB and local companies such as case study A. This period of analysis and

contemplation has certainly helped the business to achieve a significant element of the rollout process right first time.

4.25 Migration Path

The active migration path of case study C is best considered as two distinct steps:-

1. **The step towards T.Q.M. and the use of the simple Lean tools.**
2. **The introduction of Lean Sigma.**

The researcher feels the journey can be considered as two separate stages with a distinct corporate push to introduce the techniques and initiatives of L.S. in a major corporate roll out activity. The financial support and corporate backing is evident in the facilities L.S. program and the initiative has had a major impact across the manufacturing site. The historical migration path can be summarised as follows:

- **The Mass Production of Pharmaceuticals** – the northern site was established to focus on the mass production of Penicillin as a key element of the UK war effort and as such it has a true mass production pedigree with small variation in the number of products produced in the early years and the change to secondary production continuing the high volumes theme in the facility. The nature of pharmaceutical production makes small batch, high variation a difficult concept to master and significant rules from national bodies make the process of change a difficult task in the short term.
- **The Development of the T.Q.M. Facility** – the roll out and use of quality circles, and worker empowerment teams in the late eighties follow the likes of case study A and also highlights a number of steps to adopt a number of the simple Lean tools, this activity would commence the foundation of C.I.

on the manufacturing site. In parallel with the retrospective thoughts of case study A, many of the initiatives would push the softer side of the business and be focused on culture and operator well being.

- **Lean Production** – the introduction of the tools of Lean Production can be considered as sporadic and without a plant wide initiative until the launch of the Lean Sigma initiative. The simple Lean tools being introduced under the T.Q.M. banner without a holistic plan and aimed at a gap filling approach that failed to grasp the need for a Lean System throughout the facility.
- **Agile Methods** – Case study C consider the theme of Agility as being a constant element on the pharmaceutical wish list, although the national pharmaceutical enforcement agencies apply a number of restrictive covenants that hamper the more flexible and agile approach the change agents would like to introduce.
- **The Strategic Master Plan and the Lean Sigma Introduction Initiative** – the initiative commenced on the case study manufacturing site in 2002 with a full scale corporate sponsored roll out initiative to develop a site wide L.S. operating structure and extensive set of L.P. and statistical tools. The roll out continues today and can be considered as well funded, highly promoted, significantly sponsored at all management levels and becoming ingrained in the fabric of the facility.

4.26 Case Study D

The author had originally selected the fourth case study site, a first tier automotive production site in the Midlands as one of the satellite study organisations because the

site fulfilled many of the specified requirements to complete a longitudinal qualitative assessment. Additionally, the site introduced an automotive flavour to the research and linked in the pressures applied to the first tier automotive supplier by the leading European auto manufacturers. The site was sold by the parent group in 2001, and as such, only limited study activity was available at the facility, with an initial five-day Kaizen activity taking place on the site followed by two subsequent one-day study tours. This activity was supplemented by the facilitation of a ten-day training program delivered by the author to two key change agents in the C.I. management team in 2000. The Midlands site was subsequently closed, demolished and transformed into building land through the course of 2002/3.

Although the sale of the Midlands site part-way through the study period can be considered as reducing the impact of this satellite study, the author is of the opinion that the Lean development of the parent group is still worthy of inclusion in the report. The development path of the parent group's in house university and the remaining manufacturing links in the group provide an excellent additional view of the transformation of an ailing UK manufacturing business into a truly world-class and globally recognised business. The key criteria identified at the commencement of the study at the Midlands site can be defined as follows:

- **Access Links** - the author had obtained a verbal agreement with the local manufacturing management team that access to key respondents would be available and that they were willing to work alongside the author over the length of the case study period.
- **Historical C.I. Developments** - the Midlands site had a significant history of continuous improvement initiatives and had made excellent progress in the mid-

1990s in its planned migration from a traditional automotive supplier that had progressed towards a TQM business and ultimately into a Lean production orientated manufacturing plant. The investment in training from the parent group gave the local management a degree of confidence about the short to medium-term future with the management and staff appearing to be optimistic.

- **Progressive Attitude to Change** - the author participated in a successful initial five-day Kaizen activity on site and this learning process highlighted a progressive and open-minded management team that welcomed the change process across the entire site.
- **Progressive Parents** - the parent organisation can be considered as an organisation open to challenges and at all times reflecting a progressive attitude of evolutionary and revolutionary change. They embrace the very latest manufacturing techniques and are constantly on the lookout for the next manufacturing advantage to increase efficiency and improve service levels.
- **Change Agent of International Standing** - the MD is regarded as a visionary and charismatic leader who understands the essential elements of the "world class" manufacturing and quality mix.
- **Automotive Focus** - the Midlands facility reflected a Blue Chip business leading the market in its own field with excellent links into some of the most progressive automotive manufacturers and the related first tier supply base.
- **A Business Facing Challenges** - the Midlands business could most definitely be regarded as a business facing challenges and competition, both internally and externally. The local management team recognised the threat and were prepared to meet the challenges head on.

- **Japanese Automotive Flavour** - the competitive pressure throughout the automotive value chain could be considered as being applied by a number of very sophisticated automotive businesses with several highly regarded Japanese customers and competitors.
- **Representative of the first Tier Supply Base Issues** - the business is reflective of the automotive first tier supply base and represents an individual market segment that has not been covered elsewhere in the study.

The author historically had gained a good level of access to the business and had participated in an initial five-day "Breakthrough Kaizen" activity on the shop floor, giving good hands on access to both managers and operators and an unprecedented opportunity to witness the workings of the facility whilst being involved in the internal change process. The Midlands site had a significant history of change management and had striven to stay ahead of the competition, over many years, through "Breakthrough Kaizen" and progressive management and manufacturing techniques. The authors study was terminated mid-way as a result of the sale of the site and the closure of the manufacturing facilities, although a number of interesting activities had been completed prior to the facilities closure.

The initial "Breakthrough Kaizen" activity, in which the author participated, focused on three bottleneck processes identified by the local management as essential, business-critical issues that required urgent attention. The three areas were focused upon by individual teams drafted from the local change management team, local operators, a Lean Sigma consultant from TBM Ltd, and selected guests. Each team consisted of ten participants with varying skill sets and degrees of experience in the

concept of time-based manufacture and "Breakthrough Kaizen". The project activities can be summarised as follows:

- **The Large Press Tool Change Process**

The team worked upon a twin set of 500 tonne sheet metal presses with an average tool change time of over thirty minutes and four or five changes per day. The key changes in the activity reflected the following:

- The team actively challenged the accepted norms of the area and radically altered the areas used for tool and material preparation pre change over.
- The activity leads to the elimination of the forklift and driver requirements in the tool change over process.
- They eliminated and re-sequenced the tool setting operations.
- Reduced or eliminated waiting times and wasted or dead time.
- Resulting in an alteration to the floor configuration and layout to reduce the floor space requirement.

Across a series of tool changes through the week, the team reduced the average twin set tool change from 34 minutes 10 seconds to 10 minutes 20 seconds. The team also radically reduced the setting scrap produced after the change-over, and many of the changes produced zero scrap with the first press stroke producing a good component. A number of basic manufacturing fundamentals were addressed through the course. For the SMED (Single Minute Exchange of Dies) activity in the press area, the team altered the raw material, work in progress and tool storage areas. Alongside alterations to the workflow and press setting schedule, the team outlined an additional 5 minutes of opportunity available to the setting team with a minimal investment of around £2000.

- **Mini Sub-Assembly and Consolidation**

The second team aimed to consolidate two mini sub-assembly activities into a single area focused upon a Kaizen "U" shaped cell, reducing quality issues by introducing single piece flow and maximising output and floor space utilisation.

The Key changes can be summarised as follows:

- The team combined the two work areas and increased the area profile, reducing the potential for either area to be used as an available labour pool to be stopped and started in the support of other production areas.
- They introduced a material *Kan Ban* material feeding system (a constant material flow system based upon a known signal) that eliminated operator movement and process down-time.
- Standard operating instructions were introduced to the area to cover all production variables.
- The area was transformed into the standard Japanese workshop management layout (5S workshop management principles) to eliminate clutter and excess movement and improve worker safety and ergonomics.

The new cell-based layout reduced the "random atomic" flow of the work in progress and the operator and increased output and efficiency by over 50% whilst at the same time compressing the layout by 60% to free up a significant amount of valuable work space. The reduction in the required floor space to house the Kaizen cell actually freed up an area of 10 metres by 30 metres, and at the same time the First Time Pass (F.T.P. = The part passed from the final inspection station and into the despatch area without the need to rework or amend any element of the

construction) rate at the end of the line was reduced from 3.3% to 0.4% over the course of the activity.

- **The Oil Cooler Assembly**

The team in the oil cooler assembly area aimed to focus upon the reduction of Work In Progress (WIP), the reduction of floor space, output productivity and balancing the area toward the needs of the customer (Takt Time = the beat of the customer) order pattern and needs. The changes can be summarised as follows:

- The team focused upon the fundamental Kaizen cell introduction methodology in this work area and established a 'U' shaped cell capable of accepting all production variables.
- The activity in the cell was supported by single piece flow introduction and cycle time compression and balancing activity to ensure all operators remained constantly active.
- Basic SMED activity was performed on all tooling and setting operations inside of the cell.
- The material feed and material presentation systems were redesigned to feature loading from the rear of the cell in the Japanese water spider format. (the Japanese term for a line component feed operator constantly providing small quantities of components or work in progress to the operators) With local parts supermarkets being established as the component pick and feed points to each water spider.
- The activity ultimately balanced the work flow pace towards the needs of the customer and the optimum takt time.

The improvements in this one area reflected a 22% increase in productivity per operator, 60% work in progress reduction, 16% floor space reduction, an internal

lead time improvement of 40% and a 6% reduction in the component manufacturing cycle time. All of the teams committed to a thirty-day action plan to ingrain the improvements, and on a subsequent visit the improvements had been moved to the next level of activity and reflected a marginal additional improvement.

4.27 The Rollout Strategy

The initial strategic direction for Lean Production rollout focused on taking the workforce and the facility through a process of awareness and training, as follows:

- **Explaining Why** - the initial phase translated the business need to a level of workforce understanding to commence the generation of buy-in at all levels. This aspect was focused on the awareness of the threat faced by the business and the potential solution to the threat. The key activity for the management team at this phase was the development, publication and ingraining of the manufacturing policy deployment document.
- **Explaining What** - the second phase was structured as a knowledge transfer activity, giving all areas the basic Lean (or Six Sigma) principles and explaining the need for a time-based manufacturing system throughout the facility. The skills teaching focused the team on the opportunity to learn the basics of the Toyota Manufacturing System and understand the chain of activity that supported the time-based manufacturing introduction process.
- **Teaching How** - the teaching of the "how" phase aims to translate the knowledge into understanding and prepares the workforce at all levels to commence the breakthrough activity process. It combines the awareness of the

issues faced by the business with the knowledge and understanding of the change required to make a break through.

- **The Action Process** - the action phase aims to consolidate the previous phases and commences the change process, focusing upon the required results and the introduction of a new way of working within the rules of the time based manufacturing system employed at case study D.

The system aims to complete the "Action Phase" in three steps, focused at drawing the individuals and facilities through the Lean learning curve and ingraining the total Toyota production system into the fabric of the business. The steps commence with the basic tools and techniques, focused upon delivering a quick and tangible benefit for the business and presenting an easily understood toolbox for the individuals to commence using. Step two focuses upon the ingraining of the tools and techniques and the upgrading of the process, equipment and machinery of the facility in line with the Toyota methodology. The third step looks to develop a totally synchronised system, supported in all areas by the principles of the Toyota system. The contents of each step can be summarised as follows:

- **Step 1 – The Focus Upon Waste Elimination**

  This step focuses the business upon the need to eliminate waste and reduce lead-time. The key elements considered by case study D include the establishment of single piece flow techniques, Kaizen cell layouts, the introduction of standard operations and the setting up of time based SMED activity. Material handling techniques are reviewed and amended to establish feeding systems and local supermarket activities if required. Workplace organisation is reviewed and addressed by the techniques of 5S workshop management and the quality

assurance activity is focused upon through *Poka-Yoke* (error-proofing) abnormality detection processes such as neighbour checking and giving all individuals the authority to stop the line. This first step brings the tools and techniques of "Breakthrough Kaizen" to the business and delivers an immediate impact to the bottom line, whilst engaging the workforce in the C.I. methodology.

- **Step 2 – Equipment Upgrade**

The second step of the plan aims to focus on equipment and systems upgrades with a drive towards changing outdated mindsets and machinery. The focus on systems looks to deliver policy deployment to all levels of the business, with an increased focus on the cost of waste in the accounting systems, 'Breakthrough Kaizen' activities in administrative areas and commercial functions. This activity is supported in the manufacturing areas with a push towards increasing the total productive maintenance program, the introduction of auto-unload lines (*Hanedashi*) and load-unload lines (*Chaku-Chaku* lines), progressing towards the Japanese concepts of autonomation (*Jidoka*) systems of flexible assembly machines and processes and automated manual processes. The aim is to deliver machines that act like humans and humans that assemble products like machines whilst the Lean message is spread into all areas of the business and begins to get a foothold in the commercial, accounting and administrative areas of the business.

- **Step 3 – System Synchronisation**

The third step in the rollout plan aims to tie up all of the Lean elements into an synchronised assembly and manufacturing process commencing with JIT (Just In Time) and *Kan-Ban* deliveries in sync with the production line, delivered to the point of use by a committed long-term partner supplier. The manufacturing plan is supported by a production-smoothing program that is able to relieve peaks and

troughs in the requirement schedule and operates in line with the Takt time of the customer. Aiming to allow for mixed model production whilst minimising the need for large quantities of work in progress and/or costly stock holding. The process and system synchronisation activity aims to tie in the individual elements of Lean and attempts to consolidate a company-wide lean system support through the supply and manufacturing systems of Lean as well as the Breakthrough Kaizen tools and techniques. The C.I. team view the system synchronisation activity as the glue that binds the individual elements of the system together, bonding the fractured individual elements into the time-based system of Toyota.

4.28 The Business

The historical roots of case study D are in the auto spares market, an area that has historically been highly competitive within Europe, mainly with established mainstream A-brand competitors from both Europe and Japan, although the demise of the Midland facility could be regarded as being based around the internal aspects of competition. Internally, other sites were available to manufacture the product and the facility found itself based upon a prime real-estate site in the city centre.

The parent group is considered by many to have a unique energy and drive; the key to this is the charismatic chief executive of the group. His vision and foresight have propelled the business from an ailing parts supply arm of a struggling British automaker to a picture of success and stakeholder wellbeing, admired by much of British Industry. He joined the business from a division of General Motors, in 1974 and has been instrumental in the growth and development of the business for over

thirty years. His forward-thinking, long-term Lean Manufacturing orientated partnership approach has done much to shape the modern identity of the group of companies, with his views and attitudes towards stakeholders and partnerships still wearing well in the most competitive of market places. He can be regarded as having transformed the group with his progressive employee relations and the embracing of best practice in manufacturing, supply and distribution. The progress made at the company is well recognised by industry insiders and admired by many. Woods (1998) quotes the MD on efficiency, integration and the partnership approach.

> "To compete, you have to get costs down faster than ever and do things more quickly; the only way to do that is by building up trusting partnerships with the supply chain. I have always held the view that for business to survive it has to work in long-term partnership with stakeholders, suppliers, workers, shareholders and the surrounding community. We are increasingly working in partnership with our suppliers, continuously striving to make our total enterprise activities from raw material to end user as Lean and efficient as possible through a process of continuous mutual learning and up-skilling."

The MD commenced the most significant chapter of his career by leading a management buy-out of what was formerly part of the Rover automotive group in 1987. The staff so treasured by the MD took over 50% of the share ownership by the end of 1998 (Mumford 1998). As a company that manufactures and distributes in the cut-throat auto parts market, case study D deals with both auto-makers and a large supply chain. The very nature of the global auto market for replacement parts brings its own unique pressure and competition was intense in the early days of the take-over. With many analysts in the city advising and expecting a flotation on the stock

market by the new MD after a sell-off of the older manufacturing aspects of the business, the city anticipated at the very least a series of closures of the decrepit and inefficient elements he had inherited. The cuts were eagerly awaited by the industry insiders. In an area of British Industry famed at the time for poor labour relations, case D had typically poor workforce relations, and many anticipated that the new management would cut the workforce hard and attempt to amputate the areas of the business that were considered troublesome.

In discussions with the management team, the author was informed of the advice and counsel given to the board at the time of the take-over. They had been advised to keep the distribution element of the business, and that this element of the business had a well-known brand name and a good reputation. The manufacturing elements had to be removed for the good of the total business; they were outdated, unproductive and inefficient. They could not compete in the Lean manufacturing world of the automotive industry and any attempt to modernise would be time wasted. This advice was not accepted by the MD of case study D, he had a vision and a desire to transform manufacturing in Britain as well as inside his own manufacturing plants. This vision prompted him to ignore the advice he had been given and commence a Lean journey to discover and implement a vision of world-class manufacturing. He commenced by building and developing a highly motivated, energetic and strong management team. His aim was to mould a strong, open, learning-related management structure that truly qualified for the label "team". They would progressively adopt the Lean techniques of time-based manufacturing and commence a transformation of the ailing factories into true world class manufacturing facilities.

Using a varied series of tactics, including almost every management technique from gentle persuasion through to strong-arm confrontation, the MD set about waking up the workforce and sent many managers to Japan to, in his words, "listen and learn". The instructions given to the study groups was always the same: "watch, observe, learn, and then, when you return to the UK, come back to the workplace and put the techniques into practice exactly as they do in Japan". He had an early vision of the need to move the manufacturing facilities of the group towards a Lean culture and understood the need to adopt the system of time-based manufacture in the broad sense, not the cherry-picked and westernised elements adopted by others in the UK manufacturing industry. This vision is reflected in the previously highlighted three-step approach towards the adoption of the Lean system. In the mid 1980s, case study D commenced schedule of discussions with the senior managers at a leading Japanese automaker, and set out on a learning process, combined with a patient step-by-step approach to develop a true partnership with the Japanese management team. The relationship developed and matured, and in 1997 a joint venture was signed for £35,000,000 of business between the two companies.

The MD understood the need to master the basics of the Lean manufacturing techniques, highlighting to his team the need to master the foundations of the time-based manufacturing processes prior to working out how to improve it. His basic starting point was based around the concept that learning and development would be key to the success of his new business. McMaster (1995) comments, "The company is now one of the top in quality and productivity in the industry." They are generally recognised in the automotive industry as generating significant process improvement, and in discussion with the management team, the business now considers that while it

is continuing to learn and develop internal skills, the greatest possible impact may be delivered by focusing upon improvement in the supplier content coming through the factory doors. This thought process was backed up by two senior change management leaders attending a Supplier S.S. training course in 2000.

4.29 The Partnership Approach

The company recipe is one of entering into relationships with mutual respect and trust, developing and growing that degree of trust as the relationship matures and develops into a long-term partnership. This philosophy is representative of the Lean methodology the management team had witnessed in Japan and had come to consider as standard practice within the group. The group of companies has grown into one of Europe's leading independently owned automotive parts and accessories companies through its mastery of the Toyota Manufacturing System and more recently through coupling the tools and techniques of Six Sigma alongside the Time Based Manufacturing systems. They have harnessed the best of world class automotive manufacturing know-how and commenced a metamorphosis throughout the group, epitomised by the development of manufacturing and logistic operations such as the exhaust system joint venture. The author's discussions with the management team in case study D highlight the acceptance of the pan-business impact of tools such as Lean and Six Sigma, with extensive use of the tools outside manufacturing and each and every aspect of the business being designed around the principles of "World Class" manufacturing. The business and its partner joint ventures can be considered to have engaged the tools of Lean and SS in a growing business portfolio, expanding into many additional areas, including the provision of total logistics services and

solutions to the automotive industry. The senior management is fully committed to the rollout of the Lean Sigma (LS) process in the transactional areas of the manufacturing process, and they have streamlined planning, forecasting, stock holding, and shipment activity in line with the best practice transactional LS practices.

The performance along the lines of the Toyota Manufacturing System and the partnership with automotive businesses that simultaneously accept the goals of the Lean process remain at the core of the business, and indeed form a solid foundation for the new shape of the company. The business has subsequently developed links and partnerships with the world of IT, mobile communications systems providers, healthcare and the defence sectors. The business trades through a number of individual divisions with specific focus towards each end customer market, and each partnership holds a blend of Lean cost structures and Agility in the unique mix designed to satisfy the requirements of the market. The prime aspects of the business remain the product development, marketing and distribution process for automotive after-market products and service networking through the established logistic process, encompassing the tools and techniques of "world class" manufacture. As a core manufacturer of Original Equipment automotive parts, they operate two joint venture companies with leading German component manufacturers, making original equipment for several British, European and Japanese vehicle manufacturers in the UK and Europe. The partnerships bring to bear the established German contracts with case study D's advanced manufacturing know-how and L.S. improvement techniques.

4.30 The Goal and Migration Path

The management team considered the company was focused on three key areas:

- **The Ongoing Quest for Zero Defect Quality** – pushing for performance to the tightest of automotive specifications.
- **The Highest Levels of Cost Efficiency** – focusing on delivering world class cost throughout the business through the continual quest to reduce waste in all areas, ultimately leading to the ongoing delivery of defect free quality at a competitive world-class cost.
- **Performing at the Levels of Service and Delivery Demanded by the Automotive Industry** – coupling quality and cost with time-phased line-side delivery that is now often a minimum requirement in the automotive industry.

The three threads are essential elements of doing business in the automotive landscape and key factors in any automotive decision-making process that involves awarding component or service contracts. The processes and systems witnessed by the author highlight the detail and precision required to be successful as a true automotive first-tier success story. The parent company of case D continues to develop and hone the cutting edge manufacturing techniques that have been learned from Toyota, Nissan and Honda and refined internally within house over the years. The firm continues to develop tools and techniques of CI, with the skills of S.S. being the most recent manufacturing activity to be absorbed into the company toolbox. The tools are currently being blended together with the e-business skills network and the company's long-held philosophy of teamwork, known as the 'Way' within the C.I. team. The

implementation of this ethos and way of working has successfully generated remarkable results throughout the Group.

Competition has played a significant element in each and every longitudinal study conducted by the author. The author's view is that the MD of case study D understood that the manufacturing businesses were not immune to the competitive pressures placed on the UK manufacturing sector over recent years. Significant customers had their focus and aim placed firmly upon the previous comfort zones of long-term partnerships, questioning the comfortable relationships and seeking cost reductions across the board. In 2001, he found that this internal relationship pressure was coupled with the external threat of the weakness of the Euro and a strong Dollar. The above financial performance in a time of significant automotive market pressure could be considered as excellent in the face of mounting economic pressures and low-cost competitive activity throughout the sectors that they have traditionally competed in.

The MD (2002) considers that much of this success is due to the continued investment in world-class tools, techniques and training for his staff. "Across our Group, we continue to see significant returns on our long-standing investment through the "U" (the Company University) in developing well-trained, highly motivated people who can be equipped with the best business tools and techniques from our 'Way' Knowledge Management System." The author believes that this investment in the people and in the 'Way' have developed a culture of C.I. and a desire to be "world class" in all areas of the business. In parallel with a number of the great design and manufacturing companies of today, Toyota, Dell, Microsoft etc, they constantly strive to move forward, with C.I. as a central element of the management strategy.

The migration path demonstrated by case study A, can not be fully considered as the facility closure curtailed the evolutionary development steps underway at the manufacturing site of case study D. The facility could be considered as in a Lean Production phase at the plant wind down with a series of milestones taking the facility from T.Q.M. to the Breakthrough Kaizen phase of Lean Production introduction. The wider corporation continued on a Lean Production path and in 2002 commenced an incremental development of the tools of S.S. A combination of the facility migration path and corporation migration plan can be highlighted as follows:

- **The Establishment of Automotive Mass Production** – the case study manufacturing site was established as a true automotive mass production facility with limited variation in the early production years and a small number of products assembled for a single automaker. The management push can be considered to be focused on achieving higher production volumes in the early days of the facility.
- **The Development of the T.Q.M. Initiative Across the Facility** – in line with case study A the focus of the facility in the eighties can be summed up as the development of quality circles, and a project culture of problem solving by task force management and worker empowerment. The 'Brown Field' site commenced practicing T.Q.M. and commenced a process to establish a foundation of C.I. that could save the site in the long term as it moved from a captive component supplier for a single automaker to a facility selling its products to the entire automotive industry. This process opened up new markets and also increased the competitive threat to the site.

- **Lean Production** – the introduction of the tools of Breakthrough Kaizen and the basic skills of Lean Production commenced in the manufacturing facility in the early nineties. The initial development of tools such as 'Just in Time' and simple signal based Kan Ban systems commenced the foundation of L.P. The activity can be considered to have developed inline with the initiative developments featured at case study A. The breakthrough Kaizen activity commenced in the mid nineties with a significant Lean introduction process aimed to establish the full spectrum of Lean tools in a mature 'Brown Field' site with limited production space, an outdated building and a mature workforce. The initial focus aimed to introduce Kaizen cells and SMED (Single Minute Exchange of Dies) techniques to drive up production volumes and efficiency and drive down delivered manufacturing costs.
- **Agile Methods** – the corporate stance can be regarded as considering the theme of Agility as being a prime requirement to support the present day automotive customer. The business is focused around Just in Time, line side delivery of self planned components to automotive partners. The Kaizen Breakthrough activity at case study D increased the facilities degree of Agility with significant reduction in tool setting times, change over periods and first off scrap production.
- **The Introduction of the Tools and Techniques of Six Sigma and the Fit with the Lean Production System** – the corporate awareness of S.S. process commenced with a series of training workshops onsite at the northern manufacturing base of case study A. The activity focused towards understanding the fit of the S.S. process with the well established Lean systems established across all of the manufacturing locations of the group,

highlighting the best synthesis approach. The manufacturing and assembly areas could be considered as already holding many of the skills of S.S. without a focused initiative such as Cost of Failure. The development of the additional statistical tools across the manufacturing facilities of the corporation will in them selves to be of benefit in the opinion of the researcher. The L.S. initiative may be encouraged by the movement of key automotive players moving towards L.S. the likes of Ford, and Saab pioneering the move towards L.S. in the recent past.

4.31 Cross Case Analysis

The need for a comparative assessment and audit process has been considered from the outset of the research and all site based visits have been guided by a simple question and assessment area matrix. The matrix is included as the tables 4.31.1/2/3/4 and can be considered as having guided the researcher to ensure that each site visit followed a similar format and that questions followed a constant series of themes. The application of a standard approach throughout the study aimed to reduce interviewer bias and to ensure the differing stages of C.I. development in the various studies could be considered and accommodated. The researcher conducted interviews at all levels of the management and operator structure and as such a differing approach was taken to accommodate the various levels, the matrix allowed the researcher to probe the same areas across the case studies with various levels of management and operational staff.

TABLE 4.31.1 CASE STUDY COMPARISON OF CASE STUDY COMPANY PROFILES

Case Study	Corporate Vs Site C.I. Culture	Business Drivers	Competitor Sophistication	C.I. Message Consistency
Question -	**Define in simple terms the corporate and site C.I. culture that is present in the case study business site**	**Define the key Business Drivers that are present on the case study site, throughout the duration of the study period**	**Define the Competitor sophistication measured in terms of the threat posed externally to the business and any changes witnessed throughout the study period**	**Define the corporate and business C.I. message that is present in the business, throughout the study period and any progressive changes witnessed**
Case Study A	Generally the facility could be considered as following the outlined Corporate Plan for C.I. – Could be considered to be leading in the areas of Six Sigma and Lean Production introduction from 1999 onwards	Cost focus in consumer industry sector and significantly more Reliability focus in the professional business area. Increasing cost pressure from Far East competition in consumer product	Competitors are focused in two distinct categories; competitive strategies required for each environment, both professional and consumer product focused and fine tuned to the sales market and environment	Slight confusion with some of the terminology of S.S. and possible initiative fatigue in some areas. Standard S.S. materials helping to deliver a more consistent message and balance with Lean Production
Case Study B	The Facility can be considered as leading the Corporate Plan in terms of C.I. from the late 1990s onwards with a distinct Lean flavour – The L.S. plan being launched in 2005 in the Northern Facility with plans to review across the group in 2006	Focused towards output & flexibility improvement, driving down waste. They can be considered as reducing stock in an industry that sells from stock. – Latterly focused more upon a S.S. / Agile approach to remedy this potential issue	The competition base is in a similar area of development to Case B. No outstanding or significantly well developed competitor has been defined – Increasing exposure to Far East Threats from small / low cost B brand competitors / own brands	Highly visible and focused Lean message with some initiative fatigue resulting from the pace of the management change in the late 1990s – Loss of 'Change Agent' impacting continuity across the plant through the study period
Case Study C	The case study site is following a well-documented, defined and structured Corporate Plan of C.I. with significant change in 2001/2 with new Strategic Master Plan for Lean Sigma giving a strong corporate identity	Research and development predominates the business plan. The Strategic Master Plan has focused significant aspects of internal competition and added to the competitive model for the facility	Competitors significantly focused upon new research and development; very little investment in commodity drugs. Internal competitors are chasing efficiency and quality to differentiate manufacturing sites	Message consistency much improved by the Lean Sigma program post-2001 and the new corporate materials, previous communication strategy could be considered as slightly fractured across site
Case Study D	Following Lean Production Corporate Plan prior to demise of site – The group ethos echoed through all companies in the group and strong lead of the M.D.	The Automotive Industry has moved towards LP, with many companies also establishing S.S. post-2001/2 – L.S. Now established in the industry and the first tier suppliers	Very sophisticated and competitive environment; many Japanese transplants into the UK with high quality offerings at competitive prices that have set a quality benchmark in the industry	Strong corporate message with a high degree of Lean content. Internal University helps with issues of consistency and material delivery across the group of companies

TABLE 4.31.2 CASE STUDY COMPARISON OF THE MANUFACTURING EVOLUTION

Business	Competition	Activity Stimulus	Comparison of Timing	Champions
Question -	**Define the competition - internal to the corporation and external - throughout the study period, with particular focus upon the changes witnessed over the study period**	**What activity stimulus has acted as a catalyst or key Business Driver through the case study duration**	**What Change has been witnessed in the business focusing on the changes witnessed throughout the study period**	**Review the corporate and business champions and message consistency of the champion in the business, throughout the study period**
Case Study A	Massive Chinese cost-focused consumer competition, coupled to quality focus by German competition in the professional field. LS viewed as addressing both areas of competition – distinct Low Cost Manufacturing strategy post 2003	LS viewed as the next step in TQ/LP Road Map with the Market pressure from Far East increasing the need for change driven the push to Mexican, Chinese and Eastern European Manufacture facilities.	Extended period in the TQ phase 1980 - 97 developed Breakthrough Kaizen process in professional areas & low volume consumers. Significant leading edge SS progress 1999/2003 in the Northern facility with distinct L.S. focus	Two distinct schools of thought over the last 15 years: the initial champion of TQ being replaced by LP/SS focused management. They can be thought of as two distinct and separate teams although TQM prepared the facility for L.S.
Case Study B	Strong internal and external competition, though little push outside of B towards L.P. Innovation is currently driving the business in one way and cost in another L.S. will help tie the two together	Case B were prompted into action by internal business pressure and understood that the current business practices would act as a road block to progress in the long term the competition will increase from the far east	Rapid progress through T.Q. Phase, slowing down in the LP post-2002. In-house processes such as Kaizen have been slow to take off. 'Kick Start' required to push the activity forward in 2005	Original champions have left case B, though current management now supporting the process and willing to push towards the establishment of L.S. activity across all areas of the Northern manufacturing facility
Case Study C	Industry focused towards research and development, and historically, manufacturing has concerned itself with high quality, agility and supply continuity, not waste reduction or efficiency improvement	Current direction stimulus is driven towards LS from the roots of the corporate T.Q. program; a series of mergers have focused the business on the need for strategic manufacturing direction and consolidation of facilities	Progressing towards TQ development in the 1990s with rapid move towards L.S. from 2001 onwards. Corporate team Pushing the time scales and activity plans: rollout to suppliers commenced in 2004	Current management team pushing L.S. process as part of the 'Global Project'. Little argument with the current plan as all managers view L.S. as essential for survival of the facility
Case Study D	Automotive Industry highly focused upon L.P. process and pushing the entire supply base towards L.P. principles. Some growth now into S.S. projects	Automotive drive towards L.P. extending to 2nd and 3rd tier suppliers in the late 1990s, but Cost, Quality and Delivery still the goal	Company in line with many 2nd & 3rd tier automotive suppliers. Pushing breakthrough Kaizen from late 1990s. Looking to push SS in 2001 and LS in 2003/4	CEO as key link, focusing his MDs to champion the process in their own businesses. Management very visual in change process.

TABLE 4.31.3 CASE STUDY COMPARISON OF THE MIGRATION PATHS FOLLOWED

Business	Shared Industrial Themes	Models Followed	Industrial Development Partners	Benchmarking Process Undertaken
Question -	**Define any shared industrial Themes present throughout the study period with particular focus upon the commonalities witnessed over time in the change management process**	**Define any models followed or activity paths that can be highlighted through the case study, with particular reference to the path in the duration of the study period**	**Define any partnerships formed throughout the study period with significant training, mentoring or shared knowledge**	**Highlight the benchmarking activity throughout the study period with particular focus upon benchmark companies considered to be "world-class"**
Case Study A	The basic L.P. development principles established can be considered as common to Case A+D and the general first tier automotive Suppliers of the UK. Now focused towards L.S. with the addition of the GE S.S. development model	The case study facility has followed the consultant TBM - Automotive based principles, mainly Toyota L.P. practices. Now following Motorola/GE - MAIC SS process rollout activity and currently adding the 'Define' phase to establish DMAIC	The core Lean Production training has been gained from TBM Ltd in line with Case D. The S.S. influences have been focused around G.E. people core training modules and roll out processes	Major Japanese reviews conducted in the early 1990s & subsequent pockets of automotive reviews departmentally focused – G.E. benchmarking performed upon the process of SS undertaken in 1999/2001
Case Study B	Case B followed companies like case A & IBM into cell based business units in the 1990s; and highlights many similarities to case A in its L.S. developments	Initial systems based around traditional T.Q.M. techniques of the late 1980s and early 1990s. Breakthrough Kaizen not fully accepted until more recently	None identified – recent influx of ex case study A management and change agents	High priority given to benchmarking - 1989-96 case A IBM, Nissan etc. case A S.S. activity reviewed in 2004 and case A L.S. progress in 2005
Case Study C	Similar progress to case A's - TCS (Total Customer Satisfaction) program of the early 1990s – 2001, focusing upon L.S. with the corporate rollout plan initiative	Not applicable in initial development phase. 2001 and ongoing L.S. model – Air Academy training program and process implementation activity plan undertaken	Little available inside pharmaceutical industry outside of key equipment suppliers. 2001 – ongoing: move towards USA S.S. with Air Academy	Some recent benchmarking outside of pharmaceuticals, case A and Nissan benchmarking activity undertaken in terms of L.S. in 2002/3
Case Study D	As per case A but also influenced by Automotive customers. L.S. focus more evident following the automotive industry moves to adopt L.S. in 2002 and ongoing	TBM – Automotive and Toyota based as case study A, but also influenced by Honda partnership. Used case A for initial S.S. training in 2001	Toyota & Honda partnerships established and also significant Training from TBM with strong link to Cardiff Lean Team. S.S. training from case A in 2001	Ongoing Automotive benchmarking & development within internal consultancy facility

TABLE 4.31.4 CASE STUDY COMPARISON OF HISTORICAL DEVELOPMENT TEMPLATES

Business	Corporate Culture Vs Facility Culture	Consolidated Process or Parcelling Technique	L.P. / S.S. Process Measurement	Proposed Next Steps
Question -	**Define in simple terms the corporate and facility development templates present in the case study business, throughout the study period**	**Define any single C.I. improvement techniques or any collection of individual techniques identified in the duration of the study period**	**Has the case study company been compared via an assessment profile? comparison information Only**	**Define the next steps identified in the case study companies and a consideration of the steps they feel they would need to take to become truly "world class"**
Case Study A	Corporate initiative towards L.P. commenced in USA. Initially focused on breakthrough Kaizen with limited use of 5S etc. S.S. kick-off in USA via ex-GE employees in H.Q. and key sites	Activity Base developed around TBM practices, although no comprehensive rollout strategy Global S.S. from 1997/8 with L.S. adoption locally from 2000 and corporate plan from 2005	**Yes**	Rollout of Kaizen cells into new facility & low cost vendor base - extension of model line concept. Push L.S. program Activities moved to CZ 2003 – Cell based assembly etc.
Case Study B	Corporate progress towards lean production, spearheaded by the Northern facility in the 1990s and the L.S. is also being spearheaded locally on site at case B	Initially the management team selected and implemented techniques that fitted a local development model – limited evidence of a consolidated process	**Yes**	Development of local information systems and cell-based planning systems 2001- additional direction stimulus now defined as L.S. adoption
Case Study C	Initial planning in L.P. commenced locally - LS commenced from USA management project and USA strategic leadership – with the Strategic Master Plan	Initial progress based around individual techniques - no comprehensive strategy until 2000 / 01 corporate strategy – now reflective of a significant and comprehensive process	**Yes**	Workforce development in L.S. techniques & break through process development. The sites L.S. Black Belt program from 2002 and ongoing skills transfer in place
Case Study D	Strong corporate culture in LP initiatives based upon core Japanese Automotive techniques (time-based manufacturing)	Adoption of proven automotive Lean total system approach – based upon Toyota principles	**Yes**	Continued focus upon waste reduction process. Kanban systems and cell structure. Press shop focus upon SMED prior to closure of site

The various case study companies' and manufacturing facilities studied throughout the longitudinal research process highlight an interesting learning process that when compared across the various case studies help to generate a much clearer view of the migration and development steps the facilities have followed, allowing focus upon the critical success factors. Throughout the study period the author has attempted to focus upon the broad analysis of the following areas:

- **The Established Culture of the Case Study Facility and the Subsequent Cultural Development Evident Through the Study Period**
- **The Manufacturing Evolution of the Case Study – Past and Present**
- **The Migration Paths Followed by the Case Study Facilities**
- **Any Development Templates the Case Study Facilities have Followed**

The core case study and three satellite case studies have been drawn from differing industries, with differing problems and issues impacting historical development and current thinking. The one element they all have historically had in common is a grasp of the need to continually improve performance, the first area of analysis performed by the author focused upon investigating the culture of the facility and any differences that were evident between the site and the corporate culture, what was truly driving the business and the sophistication of the competitor base.

- **Comparison of the Corporate Culture of C.I. against the Case Study facilities C.I. Culture** – in looking to define in simple terms the corporate and business cultural similarities that are present across each of the case study business sites we have discovered two distinct schools of thought.

(1.) Local planning and leadership witnessed most significantly in the review of the culture present in case study B. This strong local element to the C.I. initiative has developed a sense of corporate leadership in the manufacturing facility, although the lack of corporate investment can be considered as a negative element impacting the site culture. Case study B reflects a facility introducing the culture of C.I. without a great deal of assistance from the corporation and to some degree swimming against the tide in terms of significant investment and roll out support from board level management. The board level acceptance that is fundamental to the case studies A, C and D is not as readily apparent in case B.

(2.) Strong corporate leadership as witnessed more recently in the L.S. initiative of case study C. The corporate support offered to case study C has delivered greater educational back up, more advanced training material, more robust project tracking tools and a robust roll out program sponsored by senior board level management, driving the entire global business and reflected strongly on the manufacturing site featured in the research. This strong corporate leadership is also reflected to differing degrees in the core study of case A and also in case D with a significantly greater investment in all elements from corporate materials, training provision, consultancy support and capital investment

- **Business Drivers** – through the study period the key business drivers present on the case study sites were considered and throughout the duration of the study period the competition from internal and external sources provided a stimulus to drive change though the facilities that featured in the research activity. Areas of commonality witnessed through the study can be considered as increasing inter-group cost comparisons, driven by open book analysis, and

increasing globalisation of all aspects of the business model. The new customer power of major retailers, buying groups, internet auctions and e.buying can be considered as driving market pressure on increasingly difficult cost reduction targets. Case study A being driven to deliver annual cost reduction targets of between 6% and 8% through the duration of the research period. The growth of new market entrants has also created an increasingly difficult undercurrent of cost pressure at the bottom end of the market. The growth of the internal competitor is considered to be one of the most substantial threats to the remaining manufacturing facilities of case studies B and C, to a great degree the internal competition has already eroded much of the manufacturing base of case study A with significant job losses through the research period whilst also forcing the closure of the manufacturing facility reviewed in case study D.

- **External Competitor Sophistication** – a distinct growth in the competitive threat can be identified in all case studies. The competitive changes witnessed throughout the study period indicate the growth of the far east as a real danger with an increasing push to enter western markets, combined with a willingness to attempt to penetrate areas that could be previously consider as having capital as a barrier to entry. The growth and expansion of the competition has been reflected across the case studies with the external threat highlighted by all facilities. The key competitors identified throughout the study period are considered by the case studies as progressing in terms of general sophistication and product offering whilst continuing to offer a reduced delivered component cost. Case study A has been significantly impacted by the growth of the low cost Chinese power tool manufacturers and the

increasing trend for retailers to offer an own branded product manufactured in China by a growing band of low cost competitors. Case study B has witnessed a growth of cheap far eastern imports with an increasingly competitive offering being shipped into the UK from the Pacific Rim. This trend is also prevalent in generic medicine manufacture and in low cost automotive spares and as such is beginning to impact case studies C and D.

- **The Continuous Improvement Message** – In reviewing both the corporate and case study facility C.I. messages throughout the study period, we witness local interpretations of the material and variable delivery in the case study facilities that are not supported by strong corporate programs. Case study B reflects the local team leading a C.I. initiative with little knowledge or resources at corporate level to support the initiative. The message propounded by case study B looks to lack the depth or clarity of the corporate message found in the other case study facilities and this may well be one of the contributing factors to initiative fatigue in case B. This can be considered as a scenario that has been recognised by the majority of the study and increasingly case studies A, C, and D are developing stronger corporate material with a greater degree of depth and corporate commitment. The standardised material used by case A, C and D is also being supported by a greater degree of multi-media material and a stronger corporate strategic intent. In the late 1990's Case study A financed the initial training material to roll out the skills of Six Sigma to the tune of over $1,000,000 and a recent investment in interactive web based training has recently been completed to ensure material is available to the remote global sales, marketing and manufacturing locations of case A. The quality of materials and training support from the corporate backed

initiatives can be considered as significantly improving buy-in and the initiative acceptance.

The individual manufacturing facilities have responded historically to threats to sales and markets by continually evolving to remain the dominant player in the market, this constant evolution has been reviewed by the author to define, is the true competitor internal or external? What is the level of sophistication of the competitive threat and what stimulus focused the business upon the C.I. activity that has been documented through the study period? The facilities evolution is also considered against the ebb and flow of the key change agents and champions of C.I. and the measures they imposed upon the business and the message they preached to both the internal workforce and external audience.

- **The Definition of the Competition** – the nature of competition has significantly changed through the longitudinal case study activity for all case study facilities with an ever evolving competitive threat of pressure internal to the corporation as well as external. Throughout the study period the case study facilities were exposed to new levels of internal open book cost analysis and corporate audit with particular focus upon the previous 'cash cows' of the business. This increasing internal competitive pressure would ultimately result in the demise of two of the four case study facilities, both facilities finding it increasingly difficult to fight the new internal enemy that is the 'global corporate internal manufacturing partner'. The previous thoughts around the strategy of fighting competition and defeating the attack strategies of a distant competitive threat have been replaced by an uneasy open book truce with low cost internal partners. The management teams in all of the case study facilities

believe both the pace and nature of competition had changed throughout the study period with ever more compelling evidence that C.I. activity may well be the only strategy to engage the new internal threat. The common thread through all of the studies is the common belief that the battleground will remain upon the delivery of:

1. **World Class Cost -** Comparable to the Best Far East Delivered Costs
2. **Product Quality**, - Constantly at Six Sigma Performance Levels
3. **Error Free Delivery** - 'On Time in Full'

- **The Activity Stimulus** – several pressures can be considered to have influenced the case study facilities in terms of C.I. development through the longitudinal study. Case A suffered from the shock tactics of 35% of its manufactured volume being lost to Chinese 'B' brand suppliers manufacturing 'own label' power tools for major retailers in Europe in a single year. This activity combined with increasing internal Chinese competition would ultimately remove all assembly production from the case study facility. The stimulus for case C would be provided by a global strategic drive to integrate manufacturing locations inherited after a series of mergers as the precursor to a number of plant closures. Case D has followed a more evolutionary stimulus provided by partnering with like minded C.I. organisations and attempting to preempt the next wave of competitive pressure from the Far East.
- **Measurement of the Change Process** - comparison from the case study facilities are difficult to make with differing levels of efficiency and performance from case to case, the focus on the changes witnessed throughout the individual case studies highlight substantial results through the study period. One observation on the case study measurement processes would

reflect the robust nature of metrics development and the improvement audit witnessed at case studies A and C had a significant impact on the management and completion of improvement projects. Both studies applied rigorous discipline to the project structure at each stage and commenced in the measurement phase with a comprehensive measurement analysis prior to progressing through the project problem analysis, improvement and completion and control phases. The additional benchmarking of companies such as General Electric by case study A highlighted the central theme of metrics development and accurate measurement as a core principle of Lean Sigma development. Case study D has historically used the classic automotive measurements of Lean Production to measure overall machine efficiencies and uptime performance, with case B measuring with a similar methodology.

- **The Champions** – The research investigated the champions of the C.I. evolution both on site and at corporate level and found a combination of local leadership and corporate vision. Site B being entirely lead by local champions and suffering significant set backs as a local champion was lost from the business. The localised initiative of case study B can be considered as very dependent on local champions and significantly dependent of key individuals. Case studies A, C and D were supported by a greater degree of corporate vision and as such benefited from a more clearly defined roll out initiative, more substantial investment in material and training and a greater degree of leadership continuity. The corporate approach of A, C, and D can be considered as being less influenced by local champions and management and benefiting more from the robust sponsorship of the global corporate leadership. To this end the corporate initiatives did not suffer such significant

set back with the loss of change agents or C.I. sponsors, the initiatives continued to roll out regardless of the changes of individual management.

- **Message Consistency** – The continuity of message and degree of consistency throughout the C.I. initiative roll out period can be correlated to the commitment of the corporate champions and the robust nature of structured corporate wide approach discussed previously and embodied in case study C. The research activity reflecting a good degree of message consistency and clarity in case study C as a result of the establishment of the corporate 'Strategic Master Plan.' The more fractured local approach of case B highlighted a slightly mixed message through the duration of the study period. Both case study A and D fall into an area between B and C and are actively addressing the development of the corporate approach and the deployment of a more rigorous and structured central message.

The migration paths followed by the case study facilities have been monitored by the researcher as they progressed through the stages of T.Q.M. development, Lean Production introduction, Six Sigma statistical management and eventually leading towards the synthesis school of Lean Sigma and beyond. This common theme is present in all of the case study facilities with a general migration through the development phases with progress towards the deployment of the tools techniques and management processes of Lean Sigma. The investigation of the case study facilities focused upon directional indicators and individual migrations paths, aiming to review the shared industrial themes that were common across the various industries, the partnerships formed, the benchmarking activity undertaken and the definable models of improvement paths followed inside of the migration process.

- **Definition of any Shared Industrial Themes** – a number of common development themes are highlighted throughout the case study duration with a number of case studies travelling similar paths, commencing at similar points and aiming for a common destinations. The key differentiator to the migration often being the different velocities the case studies are travelling. All of the case study facilities can be considered as commencing from the roots of T.Q.M. having established a foundation of C.I. in the early nineties. In the case studies A and D we see two facilities that had progressed towards the area of Lean Production historically having followed a Toyota manufacturing system based Lean development path. The basic training and guidance being provided to both case studies by the same international Lean development and training consultancy and as such the two facilities shared many common practices and processes that could be considered as Lean best practices. Case studies A and C progressed through the introduction of S.S. at differing times, with a three year gap between the roll out initiatives, although the accepted American G.E / Allied Signal Six Sigma methodology could be considered to be common between the two studies.
- **Review of any Definable Models followed or Activity Paths** – case study A and D can be considered as initially following the time based Lean Manufacturing strategy of the international consultancy TBM Ltd. The activity map is based significantly upon the principles of the Toyota manufacturing company and focused upon the establishment of the base Lean principles into the manufacturing facilities through time constrained introduction activities and skills workshops. This activity has been historically supported in case study A by S.S. developments in line with the established processes of

Motorola and subsequently developed by the General Electric Corporation. Case study A can be considered as following the path flowing through the early T.Q.M. methodology based around the establishment of quality circles and the dissemination of worker empowerment, towards the automotive principles of Lean Production development, Six Sigma growth and eventually to the synthesis approach of Lean Sigma adoption. Case studies B,C, and D also commenced the migration from TQM roots and all progressed towards Lean Production as the next step on the path prior to commencing various levels of Six Sigma statistical management. Case study C. can be considered to have committed fully to the synthesis of Lean and Sigma with the strategic master plan and the American Air Academy consultancy creating a definitive step by step training plan towards the full understanding and acceptance of Lean Sigma. Case study B and D can be considered as following a more evolutionary move from Lean to Lean Sigma with both companies progressing with a degree of caution to ensure they do not detract from the solid Lean base they have established.

- **Analysis of any partnerships formed** - throughout the study period various partnership approaches became evident, both with significant training providers and industrial partners to aid in the mentoring process and in the dissemination and sharing of knowledge. Case study D has traditional strong roots with automotive partners such as Nissan and Honda that have significantly aided case D in the mastery of the systems of Lean automotive assembly and supply logistics. Case D turned to case study A in an attempt to lean the skills of Six Sigma and the early black belt training activity was conducted by Master Black Belts from case study A. Strategically the case

study businesses have attempted to formulate partnerships with leading practitioners to gain mutual advantage, this is extended into the first tier supply base by case A and C to partner with the key players to drive cost, quality and supply advantages. Both case study A and C have rolled out the skills of Lean Sigma to the key first tier supply base with case study A actively preaching the partnership approach with the most significant suppliers, performing Cost of Failure assessment activities and improvement workshops on site in the supply base.

- **Review of the Benchmarking Activity** – the active benchmarking process can be considered as taking place throughout the research period by each of the case study facilities, with several of the case studies benchmarking each other over the extended period of the research. Also highlighted throughout the study period was the use of benchmarking the facilities considered as 'best in class' in C.I. fields with case study A benchmarking the likes of G.E. super abrasives in Ireland and the Nissan automotive assembly facility in the north east as an example of this focus upon the leaders in the field of a given discipline with particular focus upon the implementation and rollout of the Six Sigma process at G.E. super abrasives in a manufacturing plant environment and the Lean Manufacturing 8D based corrective action processes at the Nissan Sunderland manufacturing facility. The general feel of the change agents in the respective facilities suggests that benchmarking helped in the following ways:
- The technique of benchmarking 'the best in class' helped the Continuous Improvement introduction team with the visioning process.

with a prescriptive corporate L.S. plan clearly defining, the training process, the training material, project selection techniques, project completion milestones, and the completed project auditing process. Much of the structure of case study C's roll out activity followed the corporate template and the quality of the material and support structure ensures a robust conformance approach throughout the roll out activity. Case study A can be considered as following a corporate S.S. rollout template with defined implementation steps and milestones and the global business of case study A can be considered as currently progressing through a L.S. development template that is being deployed corporate wide. The development templates of case B and D are not readily evident and can be considered as lacking the fine details of the Lean Sigma linkage, although both case studies commenced following structured Lean Production development templates.

- **Skills Focus** – the author has focused upon a search to identify activity across the case study facilities upon the following areas:

(1.) Single usage of C.I. improvement techniques or tools in any case study.

(2.) A more holistic collection of individual techniques loosely parcelled together.

(3.) True acceptance of the value of the full set of the tools of Lean Sigma alongside the project management process of S.S. Identified as being used as a true C.I. tool bank.

No case study can be considered as following (1.) the single C.I. improvement tool strategy with case study B and case study D following (2.) a more complete set of improvement tools primarily focused around the tools of Lean Production. Case study A and C can be considered as focusing training and

improvement activity around the development of a more complete set of L.S. skills, with the prime intent of the current training being placed upon the development of a full toolbox and a more holistic improvement methodology.

- **Review of the Next Steps –** All of the case study companies had considered both strategically and operationally the next steps for the business, highlighting a number of initiatives they considered they would need to take to become a truly "world class" manufacturing businesses. The depth of the strategic review process varying from facility to facility, with the case study facilities with a more corporate sponsored approach and track record reflecting a greater degree of central resource and research commitment. The more localised facilities such as case study B have performed a more pointed, local review that is focused upon the needs of an individual facility. The common thread in all of the studies focuses upon increased manufacturing efficiency and supply focused agility with the ability to build to order or finish a customer bespoke product at a late point in the supply chain. This area of future development is an area ripe for additional research, with each facility contemplating the next strategic development steps.

The mix of Lean Production and Six Sigma skills actively used in the various case study facilities have been measured by the researcher at the commencement of the research activity initially focused upon identifying the Lean tools used and latterly focused also upon the Six Sigma skills that could be considered as being practiced at the conclusion of research activity. The measurement process aimed to cover a broad spectrum of general L.P and S.S. skills and to offer a holistic overview of the facilities tools and technique usage. The measurement tool is included in Appendix 2 and has

been developed from the TBM Lean Production skills measurement process to allow the researcher to take a more holistic overview of the site wide skills penetration.

The two figures aim to highlight the following areas:

- Figure 4.31.5 highlights the Lean Production and Six Sigma skills usage at the commencement of the study process through a general measure of the tools and techniques of the two initiatives, highlighting the penetration and usage witnessed by the author on site at the case study facilities. The measurement process has been performed by the use of the assessment matrix highlighted in appendix 2.

- Figure 4.31.6 highlights the skills usage at the conclusion of the research study period and highlights the skills development and penetration levels at the end of the research process, and reflects the migration status in the individual studies. The measurement process has again been performed by the use of the assessment matrix highlighted in appendix 2 and after interviews with key change agents and practitioners.

FIG 4.31.5 - DEVELOPMENT OF LEAN & SIX SIGMA TOOLS IN THE CASE STUDY FACILITIES AT THE COMMENCEMENT OF STUDY

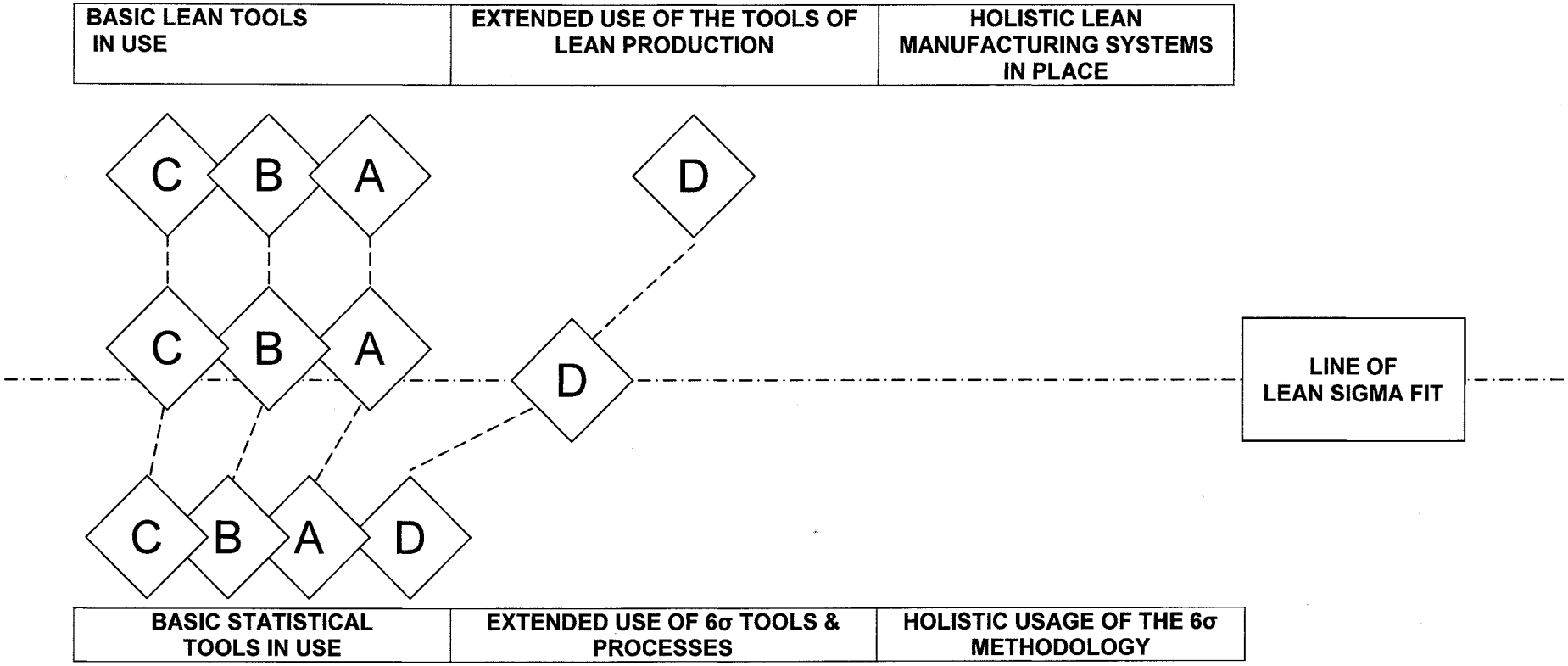
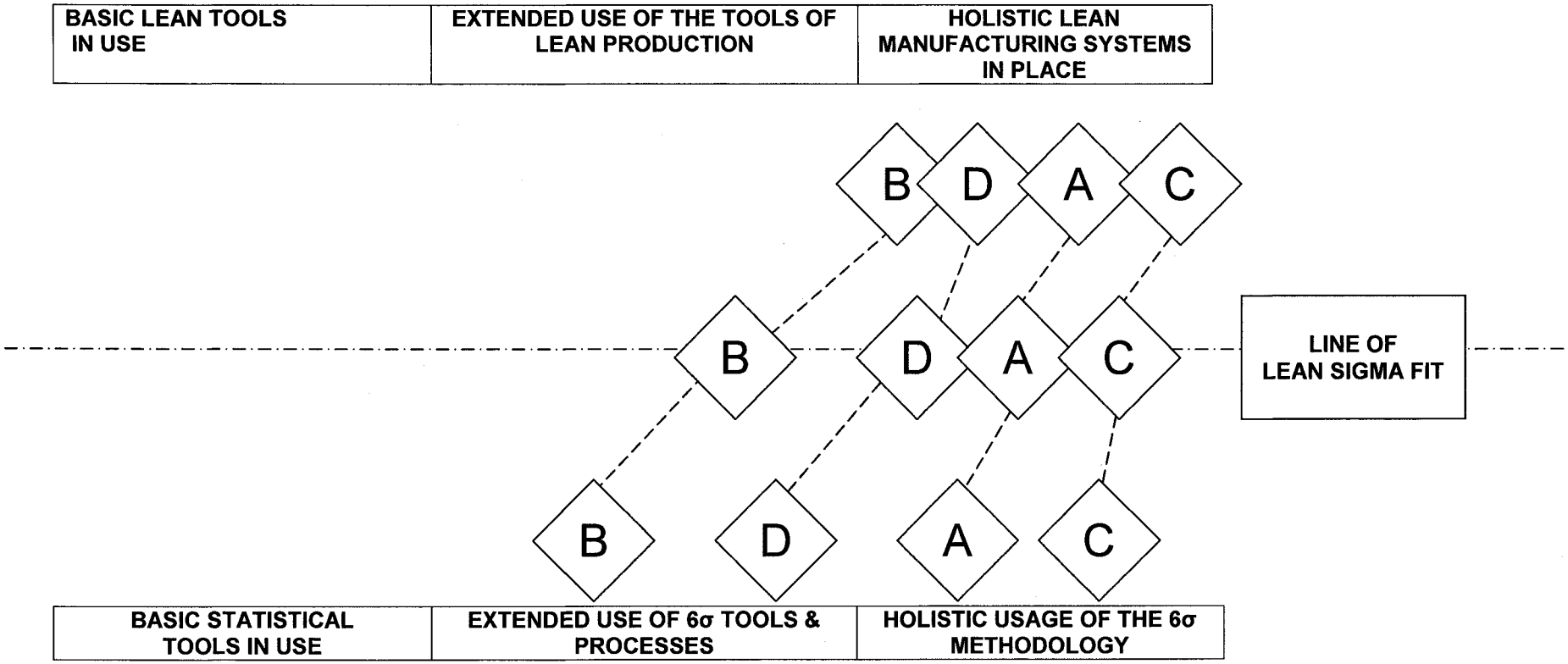


FIG 4.31.6 - DEVELOPMENT OF LEAN & SIX SIGMA TOOLS IN THE CASE STUDY FACILITIES AT CONCLUSION OF STUDY



Chapter 5.0 The Synthesis and Findings of the Study

Re-visioning of the business as a whole is appropriate following assessment of where we are. – John S. Oakland 1999

The longitudinal nature of this research project has enabled the author to witness significant industrial change across the landscape of the case study facilities with many of the observations noted in the key case study being reviewed in parallel in the satellite studies. The case studies were selected from differing industries and unrelated market segments, yet all exhibited the pressure and threat of increasing internal and external competition. The shared competitive pressure across the case studies resulted in a rapid process of evolutionary change as each of the studies fought to keep up with the increasing tide of competition. Through the course of the research program the solution proposed independently by each case study was increasingly a form of synthesis of the tools of Lean and Six Sigma, developing a new C.I. tool box focused upon the perceived market threats they increasingly faced through the study period. In discussion with one key change agent the motivation for the migration was considered to be "new solutions required for new problems" combined with the structural approach to delivering improved C.I. performance. The performance improvements of case study A, reflecting the power of the synthesis of tools of Lean and Six Sigma, as follows:

- **Manufacturing Efficiency Improvements** - through the course of the study period the core case study focused the tools of Lean Sigma towards achieving manufacturing efficiency improvements (units built and shipped against units planned to be built at maximum line rate) and achieved significant progress, migrating from a reported 84% at the commencement of the study activity to 95% at the studies conclusion.

- **Cost Reduction** – audited cost reductions were delivered in the region of $6,000,000 per annum year on year in reduced finished product costs.
- **Delivered Product Cost to the Customer** – audited annual product cost reductions averaging 6% were achieved and delivered to the customer throughout the project time scales.
- **Floor Space Reduction** – projects targeted at floor space utilisation added 45% available manufacturing floor space in a two year period and allowed significant elements of sub contracted components to be drawn back into the facility to contribute towards the cost reduction targets.
- **Production Volume** – increased in the region of 3,750,000 units / annum in the course of the research in parallel with the efficiency improvement.
- **Employee Involvement** – over 250 greenbelts were trained on site and actively completed two or more audited improvement projects.

5.1 Literature Review Process

The literature review has been progressively constructed and is the result of both the author's general interest in the current field of world-class manufacturing and the study of its history. The initial aspect of the study aimed to place the recent C.I. activities in context with the groundbreaking work of visionaries like Ford and Ohno. The author has attempted to frame the recent developments alongside the foundations of world-class manufacturing techniques and the pioneers of the continuous improvement movement. A historical study of the roots of C.I. has provided an excellent foundation upon which to build a knowledge base of the more recent developments and is recommended by the author as an excellent way of establishing

an understanding of the current work in context with the breakthrough activity of the early C.I. pioneers. The literature review has highlighted a number of themes that would later become apparent in a number of the development cycles of the case studies. One such example can be considered as the establishment of the principles of Agile production within the development of L.P. in a number of the case study facilities. The activity was first reviewed in the Literature assessment and became evident as a number of organisations attempted to become more customer-focused, incorporating elements of Agility into their L.P. development programs. The case studies attempted to focus increasingly on customer satisfaction alongside Lean and the author feels the need for Agility highlighted in the literature was independently picked up by the case studies, as they recognised the needs of the customer required a similar level of focus as the continual quest to reduce "*muda*" or system waste. The early identification of this trait enabled a weather eye to be maintained upon this area as it became increasingly apparent to all involved as the case study organisations progressed along the Lean learning curve. Within the case studies, case study B made a noteworthy attempt to react swiftly to demand, even if it required additional stocking of core products or components to achieve this customer-focused level of Agility. The author has also witnessed case study A's continual investment alongside strategic supply partners in "Supplier Managed Inventory" (SMI) to add this degree of flexibility in the supply chain and target the reduction of customer lead times. Discussion with both case study facilities highlighted a growing awareness of the need for flexibility alongside time based efficiency.

The improvement methodologies studied through this longitudinal activity have not developed in isolation, and complementary approaches are evident in each of the case

studies. The L.P. businesses reviewed had substantial elements of the statistical quality management methodologies and reflected many elements of S.S. tools and techniques long before they considered that they had introduced the methodologies of S.S. It should also be stressed that prior to adopting the 12-step S.S. improvement process, all of the case studies had at least a basic project management system, and several had previously been running a "Task Force" improvement process. This is highlighted in the author's study tour at Nissan Washington in the summer of 2002, revealing the approach that one of the UK's foremost advocates of LP is taking to S.S. Nissan are striving to learn the S.S. 12-step methodology and improvement process and feel that it will continue to strengthen the solid foundation of L.P. on site at one of the most productive automotive assembly facilities in the world. A form of Six Sigma, termed the "Value Up" initiative, has now been introduced globally by Nissan. This process is married to the traditions of Lean Production to form a version of Lean Sigma at Nissan plants. They feel the project's 12-step structure, alongside the S.S. tools, will be significant in the next step of waste reduction and efficiency improvement at Washington. The literature assessment highlighted that practicing S.S. facilities in line with Nissan had previously strong and structured project management systems in place prior to the establishment of either S.S. or L.S.

A number of the case studies can be considered to have themselves commenced a combined literature review and benchmarking activity with case study D very much involved in understanding the synergies of the two approaches and the interweaving of the complementary processes of S.S. and L.P. They have long advocated the Lean methodology in the first-tier automotive supply base, and commenced the learning curve of S.S. in 2001/2 with benchmarking at companies such as case study A.

The author has completed a significant literature review to complement the case study structure and considers the approach of developing an extensive and broad grasp of the field of knowledge to be essential to the research project. The use of the case study approach is complemented by a solid foundation in the history and evolution of the elements of world-class manufacturing and gives significant insights into the individual development paths and cultural development of each of the case studies. The general study of the subject, combined with a background as a practitioner, has helped in the understanding of many of the subtle nuances of the case studies.

5.2 Commencing With Lean

All of the case study companies commenced the move towards the form of time-based manufacturing that we know as Lean Production from a broad foundation of T.Q.M. Although all of the studies can be regarded as having different experiences of T.Q.M. it can be considered as a fundamental element and foundation in all of the studies. The monitoring and measurement of the migration towards Lean Production has highlighted a number of differing angles, and although all practice varying elements of Lean Production, they are often visually different.

Case study D and A initially introduced Kaizen breakthrough initiatives in the early days of the L.P. development cycle, commencing in the mid 1990s with workshops for senior and middle managers prior to a full-scale roll out plan. They considered this an excellent Lean commencement strategy and a highly effective fast-track start-up process, delivering significant buy-in from the shop floor through to senior

management levels. The process fosters a culture of "just do it" and delivers rapid results, from the transformation of previously inefficient or non-productive process or areas into single piece-flow Kaizen cells with significant efficiency improvements. The use of Kaizen activity as a Lean kick-off tool requires considerable consideration by the steering committee with regard to the next steps in the development process. The Kaizen breakthrough initiative requires a significant support structure to ensure that the activity is not a superficial, under-funded failure.

Case study A focused the breakthrough tool on a single improvement area to post a significant marker of quick successes to the shop floor. The Kaizen breakthrough activity focused the introduction team on the delivery of floor-space reduction in an over-crowded facility, and as such, delivered additional visual evidence of the success of the process. The resulting project completion would free up one quarter of the assembly floor to establish a professional power tool assembly plant. In both case A and D studies, individual managers commented upon the need to strengthen the approach with additional tools and techniques, rolling out a more company-wide approach founded upon training and development workshop activity for a total Lean approach after the initial launch phase of Breakthrough Kaizen. The researcher concurs with a number of published authors, including Friedli (1999), who warn against strategies that push individual tools. They reflect the dangers in this approach and suggest that the half hearted approach could do more harm than good in that the diluting of the LP structure by those wanting to perform instant change or "Kamikaze Kaizen" could have a significant long-term detrimental impact. Throughout the case studies, the workforces have been highly sensitised in the introduction phase, and any mistakes during the rollout phase are difficult to correct and resolve without

significant program setbacks. A compromise approach is called for, requiring a balance between the management attraction of the instant change Kaizen breakthrough process and the decade-long development of the incremental approach.

The key case study change managers considered the need to be flexible as well as Lean as an essential element of the manufacturing mix, and were generally unable to see any significant differences in the Lean and Agile approaches. They may not have been familiar with the field of Agile research, although all could be noted as understanding the requirements of the blend of Lean skills and a flexible or Agile approach to the manufacturing requirements. The researcher would focus upon the review the of the broader business definition of Agility offered by Carrie (1999), in which the key elements are defined as the ability to rapidly alter production volumes and product specifications, to identify and meet emerging customer requirements, to adopt emerging technology and to deliver the total service package. All of the case study organisations have attempted to progress towards the more Agile model, with products and service offerings altering as they developed a more sophisticated approach to this problem. This reflects the adoption of the common-sense elements of the Agile school of thought by the case study companies without formal exposure to the academic aspects of the process.

Each of the case study organisations can be considered as competing at the high end of the respective markets served, and as such, the push to a more Agile environment is unsurprising, as improved service offerings will always have additional appeal at the high end of any market. The products provided are at a premium quality level and the service level required from a very discerning customer reflects this need in the

manufacture and delivery of premium product offerings. The scenario is highlighted well by the products developed by case study A over the last ten years. They have progressed towards the high-end professional market with low-volume, high-complexity products and greater technical understanding of the specific market niche they are serving. The professional product range requires a significantly more Agile approach than the traditional low-end consumer power tool product now being supplied by Chinese "non-branded" (no-name) competition. The need for case A to become more Agile increased as the no-name Chinese consumer product commenced the erosion of the companies market share in the very competitive European DIY market. They had strategically chosen to fight the competitive threat on design, quality and flexibility in the professional market, and as such, the need for an Agile approach was pushed forward by the needs, requirements and expectations of the target European market of professional power tools and the fact that key European competitors, such as Hilti, are focusing on an Agile, customer-focused approach, from manufacture to individual customer collection on-site for repair or service.

In the manufacturing studies of Burgess (1994), he comments that, "there does not appear to be an identifiable manufacturing characteristic called Agility". This is backed up by the present case study activity, with the researcher identifying many differing elements across the case study organisations that may impact on Agility and flexibility. The vast majority of the feedback received from one-to-one management interviews across the case studies reflects the acceptance of a blend of both approaches and an approach towards the synthesis of the best of both schools.

5.3 The Development of Six Sigma

The initial references to the concept of Six Sigma became apparent to the author in the late 1990s as case study A commenced a S.S. introduction drive, attempting to combine the Lean tools with the methodology of scientific management techniques. The author approached the technique with an open mind and quickly came to the conclusion that a synthesis of the Lean Production and Six Sigma techniques formed an excellent next step for the facilities C.I. activity. Case C commenced the introduction of elements of the process in 2000/1 within its own facilities and shadowed case A with a European supply base rollout program in 2004. Case D commenced the S.S. adoption process in a number of its plants and practices in 2002, although it tended to openly discuss the activity as a Lean development and adhered rigidly to a Lean model of improvement in the early stages of the technique. From early 2000, it was apparent to the author that the techniques and processes of S.S. would become a substantial element of each of the case study reviews and would play an increasing role in many of the leading UK manufacturing organisations' C.I. activities.

The author feels that the base elements of the introduction framework and the 12-step project process of S.S. can be considered to be well distributed and widely known, having been discussed and documented by a significant number of eminent authors. Breyfogle (1999) and Harry et al. (2000) offer a standard model and a standard set of statistical tools. The introduction of the standard S.S. framework studied at case studies A and C highlight the aim of delivering a set of fixed project guidelines. They are evidently used by both practitioners and management champions and have become

ingrained in the fabric of the two businesses. In the author's opinion, the 12-step process is acting as a practical project tollgate system in both businesses, with projects being on hold until the required results are provided to the site champion or line manager responsible for auditing them. All improvement projects are subject to audit and approval at the end of each phase, and are not allowed to progress from one phase to another unless sign-off is completed. A common feeling of the change agents and managers both in unstructured interviews and discussions through the course of the case study process indicated that the project rigor and discipline of S.S. had helped to develop a more structured, though at times more autocratic, improvement process. Case study A added the process to the very dynamic and fast moving manufacturing environment at the northern facility and found it to be a significant complement to the existing process improvement systems. The business "Task Force" project management technique has historically progressed at a breakneck pace in terms of improvement introduction, and any steps not considered essential may well be missed or merely receive lip service. Team leaders have focused on the steps that they consider will have an impact on the final introduction schedule of the 'Task Force'. The successful leader was often accused by both the work force and the team members of bullying initiatives into existence and acceptance.

The incremental nature of the S.S. initiative ensured a more comprehensive and wide-ranging review process, inclusive of a more substantial peer review and buy-in activity. The audit process also tended to add structure and sign off to the final assessment and learning phase. The well-documented rigor of S.S. has also fitted well into the tightly regulated and highly documented approach of the pharmaceutical facility reviewed in case study C, and is very much in tune with the pharmaceutical

industry and its control practices. This reflects the roots of S.S. in the process-based industries, which have many synergies with the pharmaceutical industry.

In a number of interviews with senior managers at case study A and C, it was indicated that the process required significant management commitment in the attention to detail needed to formally progress through improvement projects. The 12-step process leaves little doubt in the minds of the management team with regard to the correct next steps and provides a simple, easily understood action plan for management that can be considered as fitting the entire site. In the case studies of A and C, the author would highlight the benefits delivered by S.S. over the last three years, though he would temper the results with the thought that they represent a significant amount of hard work and dedication, not a magic wand. The author concurs with the views of Riley (2001), and he would highlight four key benefits to the global business of case A:

- **It can Significantly Influence the Bottom and Top Line of the Business** - this is born out by the results of the case study activity, with case study A globally declaring $100 million of project benefits in 2002 and $6 million from the case study site.
- **It instils a Level of Discipline in the Organisation's Decision-Making Process** – this is especially evident around the area of policy deployment. This again is supported by the senior management team in case study A and is one of the attractions of the program.
- **It Allows Increased Differentiation Between a Company and its Key Competitors** – case study A possibly felt the need to follow the accepted trend on Wall Street, although case study D was attracted purely by the project benefits,

although it is recognised that possible differentiation will be reflected upon S.S. suppliers, setting them above other first-tier automotive suppliers for a period.

- **It Increases the Organisation's Ability to be Sustainable over Time** - through the development of a common language and a solid understanding of what is important to the business. This common goal is reflected by all of the significant S.S. businesses visited by the author, commencing with GE Super-abrasives in Southern Ireland in 1997/8. A sense of closer ties to the corporate goal of S.S. set by Jack Welch and a stronger sense of business direction could be identified.

5.4 Top-Down Commitment and Cultural Acceptance

Throughout the structured interview process, all participating case study organisations could be considered as agreeing upon the need for top-down commitment and significant involvement from the senior management team. The need for support from the very top at the introduction stage and early development phases of the initiative is noted as critical to the success of the initiative, an observation that is confirmed by all of the initiative leaders in the case study businesses. The author's views on the need for top-down support in the introduction process are reflected in the research conducted by both Riley (2001) and Puuar (2001), although the simplistic view of management support does not consider the organisation infrastructure or the type of management structure that is currently in place, but simply asks for management commitment to support the initiative. The author believes that this is a given in any improvement program, the question for senior management should be "*How* do I constantly support and monitor the initiative through the life of the project?" and not "*Do* I support this initiative?"

In terms of the cultural aspects, the scope of the study has been restricted to a number of UK organisations, though in case study A, the author has had significant exposure to the first-tier European supply base. The work of Hampden-Turner and Trompenaars (2001) and Crom (2000), which counsels the need for a thorough study of the individual business culture and the selection of management and implementation approaches that are suited to different European countries, is acknowledged. In the introduction of S.S. to the Italian supply base of case study A, the author consulted local experts and much of the Americanisation was stripped from the training material in the translation to Italian. The material was also delivered in Italian, as 80% of the recipients had no working knowledge of English. Any attempts to force-fit the American material and training program may have resulted in failure at the launch phase.

The author concurs with Crom (2000) and advises against "blindly adopting approaches that are based on an American style, and being wary of putting emphasis on the capability of talented, well-trained individuals to get results no matter what it takes." Crom highlights a trait that is evident in case study A, reflecting the American management style that is apparent at times in its European manufacturing sites. The danger of trying to enforce the American terminology and structure of S.S. in Europe without consideration of the acceptance implications is reflected well in the author's activity while establishing the program in Italy. The focus that Crom (2000) places on the consideration to be given to the combination of organisational culture and the unique national cultures in Europe are considered to be well placed. The consideration of the correct cultural blend is essential in the introduction phase and in the development of the launch program and training approach for each multinational

organisation. The author's experience of launching the process in 1999/2000 in Northern Italy and also with a range of first-tier German high technology suppliers leaves him in no doubt that the standard American S.S. introduction pack is unsuited to pan-European introduction initiatives. One training session in case study A in early 2000 (ten days of intensive Green Belt introduction for twenty students) saw seven different nationalities represented and a broad spectrum of technical English ability.

A number of European suppliers are noted as recording some concern about the request of a major English customer to launch a North American initiative. The training material used is in English and the software package, minitab, is only available in English and French (a translation made available for the Canadian market). The very terminology of S.S. having a distinct American feel with martial arts connotations did not always fit in with the previous quality and improvement programs of the organisations. It is noteworthy that the motivation of the key suppliers was greatly improved by the fact that other major corporations, including Philips, Ford, GM and Volvo, commenced similar rollout processes in 2000/2001. The adoption of S.S. by a wider selection of Original Equipment Manufacturers (OEM's) helped with the program's credibility and with the acceptance of the message by the European audience. The terminology of S.S. with its distinct, overt American connotations requires a degree of consideration prior to embarking upon a European launch of S.S. and a number of companies have attempted to find a set of more culturally acceptable terms. In discussion with Polaroid, the change management team indicated that they had decided after strategic consideration to refer to the program's "Black Belts" as "Variability Reduction Leaders" or VRLs, feeling that the term flows logically from past quality control efforts resolving many of the

doubts around the terminology of S.S. The author appreciates that the very phrase "Black Belts" requires a definition within the organisation, whereas the phrase "Variability Reduction Leaders" was immediately understood on the shop floor and by the majority of the workforce. The adoption of this terminology gives Polaroid a more pan-European acceptance through all levels of the business. Similarly, in discussions with the Nissan team on the C.I. initiative termed the "Value Up" (Six Sigma) project, it emerged that they had decided to replace the use of the term "Green Belt" with "V facilitator" and use the term "V Pilot" to replace "Black Belt". The author appreciates the feeling within Nissan that the terminology would offer a closer fit to the firm's culture. The management team at Nissan Washington were very cognisant of not rejecting the long history of C.I. activity in favour of a brand new program. The terminology to be used should be considered by all organisations approaching the initiative for the first time, with due consideration to:

1. **The established culture of C.I. on the manufacturing site.**
2. **The historical development paths followed by the business and the site.**
3. **Any specific cultural considerations or developments.**
4. **The corporate interpretation and projection of the initiative.**

Senior executives at case study A believed that if the American terminology of S.S. had been changed, Wall Street may have viewed this in a negative light, seeing it as an implication that case study A knew better than GE or Motorola. The President of case study A, gave this explanation to the author in June 1999, emphasising that, "we will change nothing from the GE interpretation." From the author's practical experience of launching a pan-European program, the terminology used by Polaroid may have helped with cultural acceptance in Germany, Italy and Scandinavia. The European launch process of any of the initiatives should consider the acceptance and

level of awareness in the business and the political sensitivity surrounding the launch. The program should be tailored to fit the regional and cultural requirements and dovetail into the current business activity. Alongside the cultural aspects of the introduction process, the introduction program should not be considered as a "one size fits all" project; the level of sophistication and the organisational structure of the business must be considered alongside a tailored, incremental introduction program. The relationship with previous initiatives and the current level of sophistication of the organisation is worthy of significant consideration prior to the construction of the launch plan. The initial candidate selection process is a critical area, worthy of significant focus. The business selected its S.S. Master Black Belts and Black Belts from the ranks of quality and manufacturing managers with experience in Lean techniques and statistical quality tools. This short-circuited the learning curves of the individuals and accelerated the introduction plan by several months. The management team selected throughout the Northern facility were defined as "High Pots" and the author concurs with this approach, believing that only the very best candidates can act as change agents. The initial Green Belt recruits were selected as a result of the dynamic approaches they had previously shown to problem solving and their proven track records of success in project management.

The case study companies selected were based on existing brown field manufacturing sites with established C.I. experience, and although representing traditional manufacturing, they cover differing backgrounds and product groups. All of the management structures tended to follow a traditional structure and hierarchy, with all of the studies differing from Thomas Pyzdek's (1999) "spontaneous enterprises". Pyzdek cites Visa as a spontaneous organisation, lacking a traditional hierarchy. The

author has no experience of such service businesses, and as such is unable to comment on the need to modify the S.S. process and the roles of the S.S. team to successfully work in such a spontaneous organization. If the Master Black Belts in this organisation work directly for a business leader and provide information only, the application is very different to the applications experienced by the researcher.

5.5 Lean Sigma

In all of the case studies, the author has recording the propounding of the L.S. approach as the potential next step in C.I. activity with one of its attractions being its ability to adapt to the problem in hand. The blending of the two techniques has been brought to the fore across the studies, and a full improvement toolbox and the infrastructure and availability of practitioners to use the tools in the drive for continuous improvement are increasingly evident on the case study sites. A combination of the common-sense approach of L.P. and the more statistical and project-based tools of S.S. is being used to drive the current C.I. activity forward in the case studies, with the blending of the Lean and Six Sigma tools alongside the roll-out strategy and project management structure of S.S. This activity has developed a more holistic approach across the entire business and has allowed a significantly wider shop-floor involvement than the engineering S.S. based programs studied previously. The combination of Lean and Six Sigma can be considered to deliver a balanced blend of improvement techniques and a support structure to aid the implementation of the raw tools. This has resulted in the shop floor interviewees expressing a sense of contribution to the change process and of enjoying more buy-in and greater involvement in the initiative. One of the considered dangers of introducing

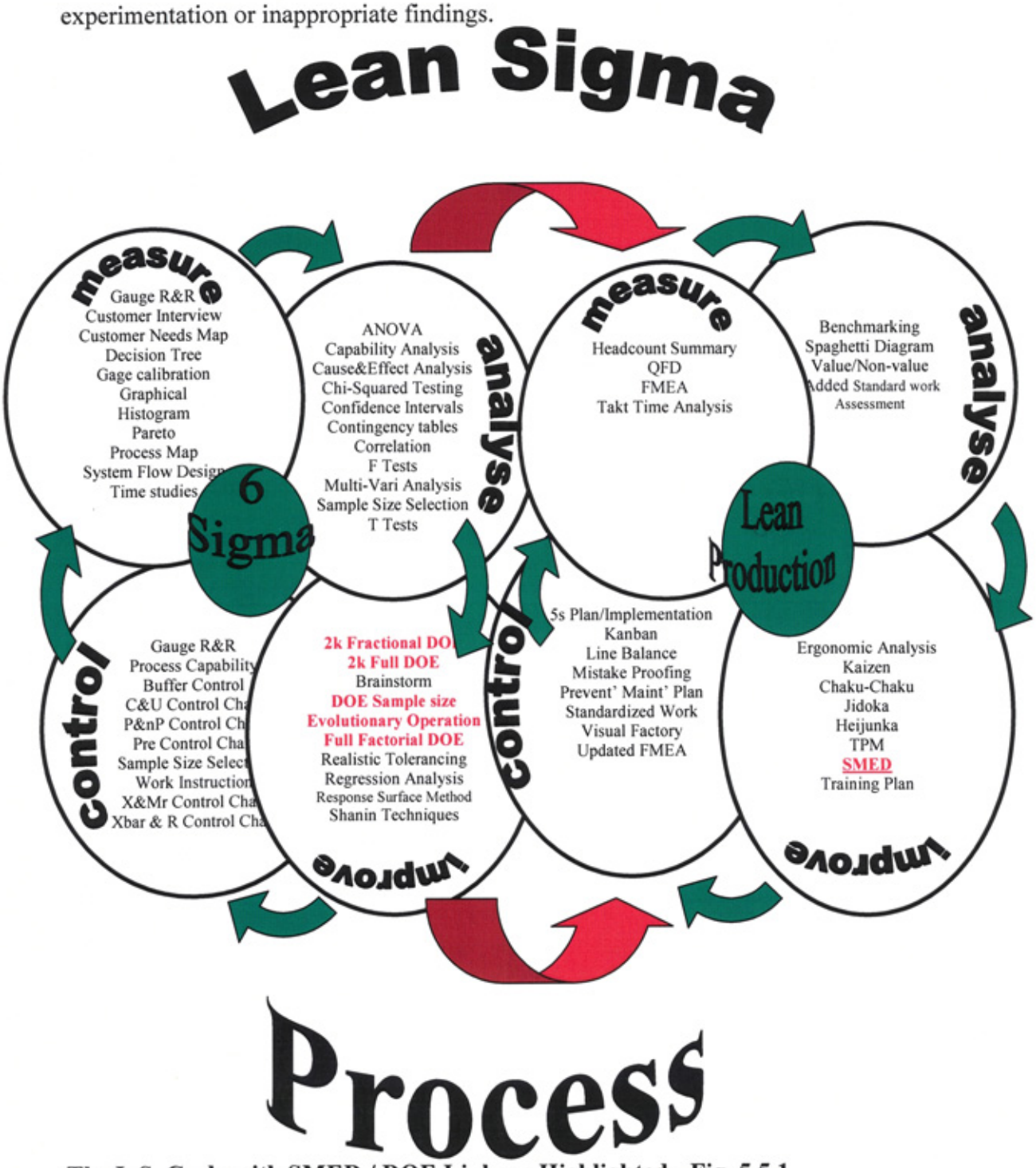
the S.S. initiative without the Lean element is workforce alienation, as they look on while management improves the business, with little contribution or involvement from the shop floor workforce, a case of deploying the tools into the hands of a few selected engineers. A number of S.S. companies visited through the course of the study have historically reflected very little of the initiative being deployed to the shop floor, and at times the direct workforce was oblivious to the initiatives' progress and results. The L.S. companies reflected greater balance in terms of total involvement and a more consistent message across the entire business. The L.S. approach has significantly improved the case study companies in terms of the assessment of when to use the appropriate tool for the task in hand and L.S. has aided the education of the workforce in the consideration of the full spread of improvement tools. The message consistency of the complete toolbox availability is essential in broadening both the appeal of the C.I. initiative and its ability to rapidly penetrate to all areas of the site.

In the author's view, when seeking to select the most appropriate tool or combination of tools for the resolution of the problem, little or no consideration should be given to the background of the tool. It is of little importance whether it is a Lean or a S.S. tool, as long as it is fitted to the resolution of the task. Pyzdek (1999e) suggests that, "the two approaches should be viewed as complementary to one another". He highlights the mutual benefit that can be delivered by blending the best of the two approaches and toolboxes, and the author concurs on this point, basing his thoughts on the completion of many projects benefiting from tools from both schools of C.I. The synthesis concept has been witnessed at a number of the case study companies, and is confirmed by the improvement project work supervised by the author and by his active participation in continuous improvement projects over the last five years. The

author has contributed towards or directly supervised over a hundred improvement projects during the last five years of the case study period. In a sample audit of C.I. tools used throughout improvement projects at case study A over 90% of the projects feature the use of both Six Sigma and Lean Sigma tools in the M.A.I.C. phases.

Significant crossover of tools and techniques is evident on projects within the case studies, with the majority of completed projects reviewed benefiting from the techniques of both LP and SS. The American consultancy TBM Ltd. were significant pioneers of the "Breakthrough Kaizen" approach and launched L.P. in a number of significant U.K. manufacturing organisations. They are now actively marketing themselves as L.S. advocates. They propound the benefits of the two techniques and the combined benefit available from the L.S. approach. George (2002) has published a book on the synergies and power of the combination of S.S. quality and Lean Speed; he comments "This is the most powerful engine available today for sustained value creation". This more flexible approach has gained acceptance globally after the initial launch of L.S. and it is often a result of the growing acceptance in individual businesses of limitations in the S.S. toolbox outside of process-based industries. Sleeper (2000) highlights the lack of continuous improvements in the S.S. methodology and advises against the view of a fixed toolbox for all problems, resulting in projects that become time-consuming and require significantly greater experimental effort to deliver an acceptable closure and sign-off. The project timescales can be impacted by the rigid S.S. toolbox, with the same end result being achieved, while several months of financial saving may well be risked by a failure to recognise the correct tool to solve the problem. The conflict can be highlighted by the two individual techniques of SMED and DOE, they can be considered as having a

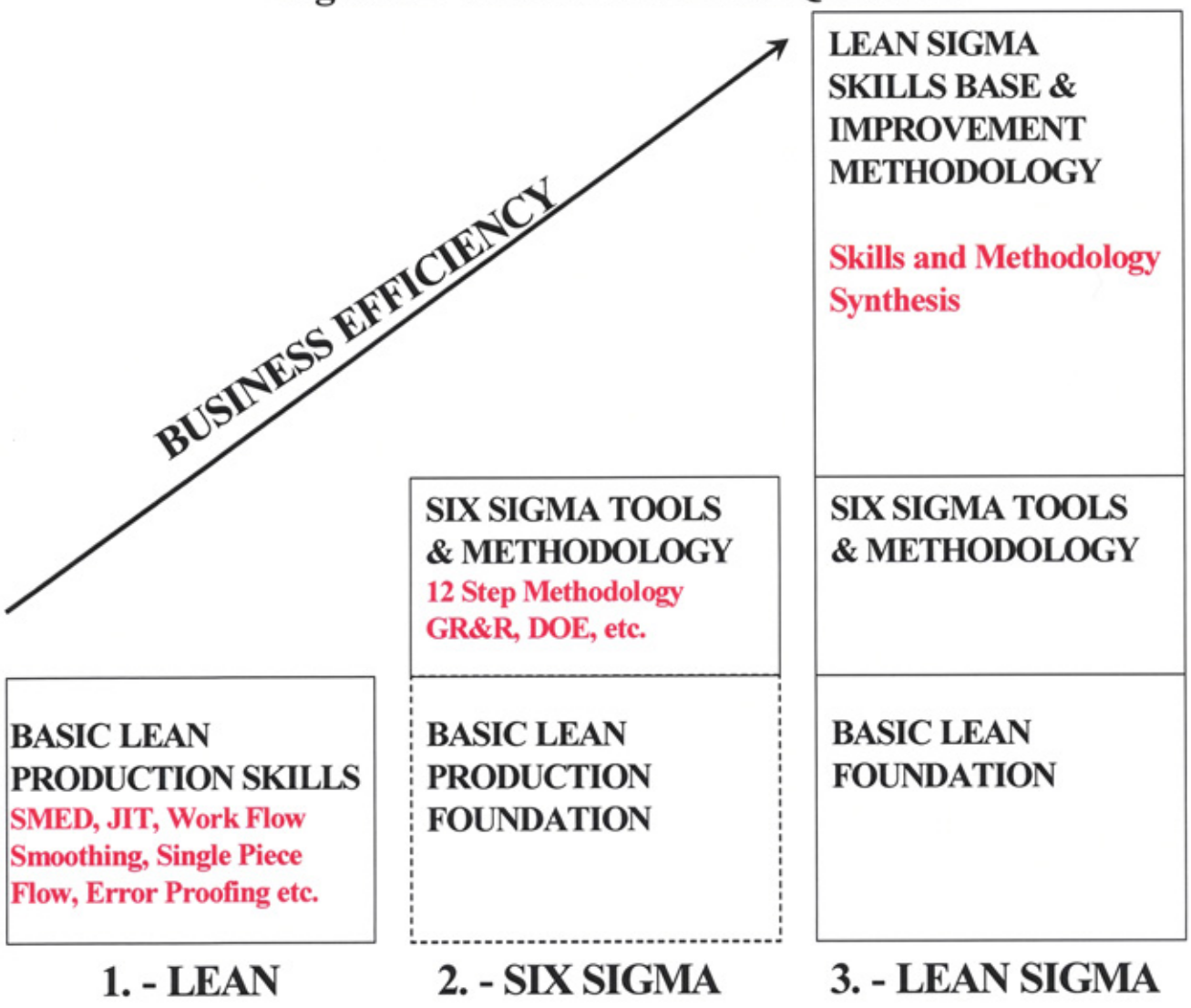
number of distinct applications, with SMED coming into its own in manufacturing change-over improvements and non-value added time reduction. DOE is of major significance in process-based analysis and invaluable in scenarios such as mould tool performance. Failure to use the tools appropriately can lead to months of costly experimentation or inappropriate findings.



The L.S. Cycle with SMED / DOE Linkage Highlighted - Fig. 5.5.1

In the course of the case studies the author witnessed the blending of the L.S. skill base and the S.S. improvement methodology delivering incremental improvements in business efficiency, and although the results are often anecdotal, change managers interviewed have confirmed the author's thoughts in this area. The above chart highlights both Lean and SS techniques fitted into the MAIC process and the mutual application of both sets of tools. Fig. 5.5.2 highlights the progress sequence.

Fig. 5.5.2 - LEAN SIGMA SEQUENCE



Two distinct chains of thought on C.I. launch have come to the fore through the research process and any business considering the strategic direction of the C.I. initiative on site should critically appraise both approaches:

- **The Incremental Approach** – the first school of thought can be identified as the more formal institutionalised approach, advocated by authors such as Zinkgraf (2000), Townsend (2002), Lavigne (1996) and Rushwin (1996). This can be considered as a more holistic business process, with the aim of setting in place the foundations that will one day lead towards the incremental mobilisation of the entire corporation, progressing towards company-wide acceptance through an incremental tiered training and rollout process for all areas of the business. The negative aspect for some observers is the time scales of the launch program may well be many years, with an initial rollout plan of between 1 and 5 years, and this may well be beyond the horizon for a number of manufacturing businesses. For those that accept the longer rollout duration, it could result in a more structured initiative founded on a progressive acceptance of the basic principles of the process at all levels of the organisation. The downsides can be considered as the time to deliver the tools and techniques to the troops and the mounting competitive pressure from key competitors.
- **The Big Bang** – the second initiative, representing a strongly contrasting school of thought, is the use of the total initiative blitz approach advocated by Adams (2001) Patton (1997) and Sheridan (1997). This approach focuses the total resources of the business to launch the initiative in a few months, via a commitment by all employees to a program of full weeks of initiative immersion, from the top to the bottom of the business. The blitz approach has immediate management appeal and can be used to deliver quick wins with basic tool training

and cultural transformation workshops leading to instant change activity. The emphasis is placed upon rapid transformation of people and processes, with a "just-do-it" attitude delivering instant impact to the bottom line and a shock treatment to the employees. The timescales are reduced, although the breadth and depth of the process may be at times compromised to record a quick win.

A process of C.I. inclusion contributed to by all levels and covering all value streams, can transform the fabric of an organisation. The synthesis of the two processes could well increase the pace of change of the introduction process and deliver the initial financial benefits or quick wins from the blitz training weeks. During the research of case study A, the site developed a week-long blitz S.S. activity, code-named "Slick Sigma", and had some success in rolling this element out to the shop floor areas at the facility. The initiative then needed the support of intensive training and employee inclusion activities, and any areas that did not have this supporting activity found the initiative difficult to sustain in the longer term. The manufacturing areas that launched the process with the Blitz technique and then followed up with a detailed training plan tended to benefit from the rapid start-up activity. They recorded good levels of initial acceptance as well as increased levels of longer-term buy-in.

5.6 Acceptance and Buy-In

Throughout the study process, an insight has been gained into a number of differing approaches used to generate employee buy-in and acceptance of the change process. In an effort to generate a process of company-wide buy-in, all of the case study

organisations can be considered as employing various tools to ensure that the message is transmitted to all levels of the business, as follows:

1 - The Development of a Cost of Failure Assessment - case study A have utilised a financially based focus tool, known as Cost of Failure (CofF) analysis. This is a measurement process based upon the financial assessment of waste in the value streams of the business. The process aims to generate company-wide acceptance of the introduction of new initiatives by revealing the true potential of the total business and the contribution of each department. The information is gathered with contributions from all areas of the business and combined to generate a total business overview of the company-wide process waste. The process encourages participation and involvement from the employees and focuses individual areas towards understanding the potential opportunities for improvement. This active participation program encourages involvement to expose the potential benefits of the C.I. program prior to the commencement of the initiative. The author has observed, from a number of case studies, that a significant number of the employees that can be regarded as becoming committed at this early stage of the project (prior to tools and technique training) remain committed through the course of the activity. The author considers that early employee involvement, combined with the establishment of a financial goal or target of opportunity, has contributed significantly to acceptance by individuals and departments at case study A. Throughout the manufacturing site, individual departments that have completed the COF assessment process have a clear view of the local contribution to the total financial opportunity that the plant is aiming to achieve, tying individuals and teams into the plant vision and project goal. This individual commitment and contribution to the total plant goal is an excellent way of assuring support and buy-in at an early stage of the process.

The consensus reached by the management team at case study A concluded that the combination of the introduction of the Cost of failure (CoF) activity and the launch of the holistic tools and techniques of L.S. had worked well in achieving both the essential degree of buy-in and also delivered a company-wide focus. The change management team worked hand-in-hand with the COF team to increase the degree of company-wide focus and commenced addressing the employees' appetite for change, increasing the initial levels of responsiveness of the individuals involved from the beginning of the program and generating greater enthusiasm throughout the program through local acceptance of the potential opportunities offered.

2 – Assessment of Cost of Failure across the Entire Business - the case study A approach of launching the assessment process across the entire business is noteworthy, being highly significant in the buy-in process. The activity schedule of the CoF rollout process is noted as aiming to involve the entire business in the waste assessment process in a single week, touching upon the performance and capability of the entire value chain. The activity was subsequently rolled out to the first-tier supply base, commencing in 1999 as the POW initiative (Productivity Out of Waste), and was a fundamental element in the drive to convince the first-tier supply base of the merits of the initiative.

3 – Development of the Cost of Failure Process as a Company-Wide Project Identification Tool - the CoF process can (or any similar waste assessment activities prior to the commencement of the L.S. S.S. initiative) help significantly in the identification of potential projects in the early stages of the initiative and stimulates the project planning process and activities. The early identification of waste in each department or manufacturing area enables the business to commence a first tier of departmental projects targeted at the elimination of the identified non-value added

activities in all areas of the business. The company-wide focus given by the CoF process allows the rapid deployment of the graduates from the initial training wave to commence projects in all areas, focused on the Pareto of opportunity to remove waste from every area of the business. This activity helps to galvanise the employees that have contributed to the assessment of financial opportunity and have now been given new skills to commence the project improvement process.

4 - The Development of a Metrics-Driven Approach - the COF process can be considered as delivering a kick-start to the C.I. initiative via the development and acceptance of a company-wide measurement process. The metrics developed at phase one will become the yardstick for financial improvements and savings for all potential improvement projects through the natural life of the C.I. initiative. The development of robust metrics processes is essential to acceptance and buy-in at all of the various levels of the business and should be considered as one of the essential early tasks to be agreed and completed by the steering or introduction committee.

5 – Value Stream Analysis - the author would recommend that the project commence with an assessment and definition of the individual value streams at an early stage of the initiative rollout process. A number of value stream analysis activities were witnessed in the case study companies, and they helped to ingrain a solid understanding of the flow of value through the business from suppliers to distribution networks. The assessment of the value stream, combined with risk analysis, highlighted a need to drive the C.I. initiative out into the first tier supply base in case study A. From the case study analysis, it was observed that case study A considered the flow of value through the entire case study organisation, commencing with the significant first tier suppliers. From this activity, they gained a management team consensus to push the C.I. process out into the supply base with key players to cement

the capability of key purchased components and critical bought out processes. In addition to the supplier training program, the development of the structured waste identification processes with regard to the key suppliers helped both project identification and benefit tracking, with significant cost reduction being offered in component price reduction. Case study A have attempted to establish the process with key suppliers as a joint financial link to the C.I. initiative and a solid foundation in each first tier supplier by establishing this as one of the business's annual objectives.

The early definition of the rollout and introduction strategy is key to the successful introduction of the S.S. / L.S. strategy, even if a strong Lean Production or C.I. culture is in place in the organisation. A number of blueprints are available from both academic circles (Snee and Hoerl 2003, Breyfogle 1999, Harry and Schroeder 2000) and commercial consultancy operations. The case studies A and B highlight the developing understanding around the need to have a calendar of change defined in the earliest stages of the initial S.S. / L.S. development planning. With the benefit of progressing in an evolutionary manner through the introduction process being echoed by the current Operations Director at case study B as they commence the L.S. roll out activity. Having experience in both facilities and previously being employed as a change agent in the case study A roll out process, he feels that he is much better placed to map out the introduction at case study B. He comments that he personally benefited tremendously from studying the organic growth and development of the initiative at case study A, learning the need to lay down a development plan to progressively introduce the strategy to case B, taking the company incrementally through the various levels of SS enlightenment.

The rollout strategy at case B may well have five distinct phases of activity over the next two / three years, broadly reflecting the activity on the case study A manufacturing facility. Nonetheless, throughout the process, individual areas and departments may well be at differing phases of awareness, reflecting the maturity of the individuals and the opportunities available thorough the process. The phases can be broadly described as follows:

1. **Introduction Phase** – exposure & acceptance of the initiative and its proposed introduction time scale – 2 / 4 months' activity
2. **Training Phase** – skills development and the toolbox rollout process across the first three waves of graduates – 1 to 2 years' rollout activity then ongoing
3. **Project Phase** – skills usage and project penetration commencing with the first wave of Green Belts – 6 months / ongoing
4. **Delivery Phase** – financial delivery, bottom line impact as measured and audited by the accounting team – 6 months / ongoing
5. **Perpetuation** – ingraining the process into the establishment - Ongoing

The individual phases at case study A flowed through a period of four years, although a significant amount of this time period was taken up in formulating the introduction strategy, developing training material and training the trainers. Case study B will be aided greatly by the local availability of skilled trainers and the growth of S.S. / L.S. training material in the public domain, supported throughout by the ability to critically analyse the successes or failures exposed in the rollout process at case study A's Northern manufacturing facility. The introduction phase at case study A aimed to generate a plant-wide exposure to the S.S. initiative and, through the cost of failure process, to commence the acceptance of the techniques and objectives of the program. The introduction phase can be considered as preparing the ground for the

developments to come and commences the process of conditioning the workforce and management to approach the introduction process with an open mind. This critical element of the roll out strategy can not be missed and the manpower investment in the preparation can pay significant return dividends through the process of L.S. introduction. The training phase introduces the skills to the workforce and commences the development of individual Green and Black Belts in the business. This element is significantly focused, in the early stages, upon the development of the internal technical experts, who will grow into the future internal trainers. The author feels strongly that in any rollout activity, focus is required to develop in-house expertise and to move on from external consultants as soon as this is feasible. Ideally, in the researchers view, the project phase should commence with the development of the first wave of breakthrough projects being focused upon quick wins, visible skills usage and project penetration into the areas defined from the initial Cost of Failure analysis. As the business develops and travels through the initial projects in waves one and two, the Design for Six Sigma (DFSS) and development of an indirect program will begin to take hold. The delivery phase focuses the management team upon the audited delivery of dollars to the business bottom line and represents intensive, maximum effort by the project teams. Alongside the financial benefits, the delivery phase aims to contribute towards quality, efficiency, flexibility and product advantages.

Throughout the case study process a number of critical success factors have been highlighted and defined that are considered to be essential to the successful implementation and development of the process of Lean Sigma.

Table. 5.6.1 Critical Success factors in the Strategic Launch of L.S.

Key Factor	Guidance	Outcome
Senior Level Awareness of The Process of C.I.	Board level awareness and representation of the benefit of C.I. is essential to preparing the parent company to accept the need for ongoing commitment to Continuous Improvement	Failure to accept the need for C.I. at board level will result in stagnation and lack of competitiveness across the business
Galvanising Strategic Intent and Top Level Commitment	The awareness of C.I. requires a progressive development program to move the board from awareness to acceptance and commitment to adopt and develop the process of C.I.	The inability to represent C.I. and develop a strategic intent at board level will result in a progressive deterioration of the business in both the eyes of the stock market and in manufacturing and logistic performance
The Process of Developing a Declared Strategic Direction	The development of strategic direction from the board level commitment may require a partnership with a progressive third party or alternatively the development of a strategic planning function tuned to the developing C.I. initiatives to lead the corporate migration process	The development of the strategic direction will need to establish a migration path from current state to desired state and the failure to commit to a corporate plan may well lead to the approach developing in to a fractured local implementation process that suffers from the lack of economies of scale and fails from under funding
Regional and Local Management Commitment	The corporate commitment activity requires a trickle down to local management with a management milestone process to vouch commitment at all levels	Plant wide acceptance may not be achieved if the workforce are unable to view management commitment at all levels – local, regional and corporate
Development of the Plant Wide Buy in Process	Commencing with a Cost of Failure program featuring all departments and areas highlighting the opportunities and challenges to all areas of the business	Failure to focus the entire business and full facility to the challenges ahead will purely alienate areas and divide the employees – if scale dictates a phased roll out process declare this at the outset to all areas
Commencing a Metric Driven Approach	Manage by metrics throughout the process	Failure to do so will jeopardise the entire project

Developing a Plant wide Grounding in C.I. Activity	Ensure the business has a grounding in the use and acceptance of C.I. activity if this is not the case a foundation approach may be required to establish the culture of Continuous Improvement	Without the workforce understanding of the basic concept of C.I. the roll out of L.S. may prove to be difficult – The incremental approach of building from an established foundation is advised
Developing the Appropriate Training Materials and Tuition Process	Ensure appropriate material is developed and available from the corporate level - without the development of appropriate training material the roll out of C.I. will be difficult, fractured, variable and lead to poor levels of acceptance and ownership ongoing	From initiative acceptance to the implementation of the tools and techniques of L.S. the appropriate training materials availability will greatly influence the take up and usage of the process – This is an area not to be overlooked or given inferior resource
Focus Upon Internal Trainers	Develop Internal Training skills at the earliest opportunity	Commitment and ownership can only be established from internal teams committed to the initiative
In- House Project Monitoring Tools	A robust project data base is required to monitor and measure progress and focus resource	Little real progress will be made without a structured and robust project management tool through the course of the project
Project Monitoring Process	Construct a regular and rigorous project monitoring activity championed by senior management	Failure to construct a monitoring process will allow opt out and diminish returns and growth
Road Block Removal Activity	The management commitment must stretch to a road block removal process as a sign of commitment	Key stumbling blocks must be removed to ensure progress and a strong message to the facility
Project Closure Process	All projects need to complete and be signed off by management as closed	Push for real results and definitive benefits not paper claims or unfounded activity that does not relate to the Cost of Failure
Financial Auditing Process	All projects require a post completion financial audit to prove a robust real saving is delivered	The saving must be aligned to the Cost of Failure process and deliver to the bottom line of the facility
Iterative Strategic Linkage	The process of strategic direction requires linking iteratively to the corporate master plan and strategic direction	Failure to link the process to the strategy will lead to stagnation and diminished growth potential

Chapter 6.0 Conclusions, Limitations and Next Steps

Perhaps the greatest criticism of the case study is that it is subjective and strongly influenced by the researcher. On this point the case study is guilty as charged – R.E. Stake (1995)

The opportunity to perform a series of longitudinal case studies has allowed a detailed insight into the marrying of the evolutionary change process with the reactive response mechanism that manufacturing businesses instinctively commence in times of great threat or rapid change. The opportunity to monitor a manufacturing facility over time has allowed the researcher to explore the nuances of the case study business and assess over time both the threats as they emerged and the responses as they evolved. In contrast to the views of Stake, the author has aimed throughout the research process to maintain an objective view and a neutral stance whilst protecting the integrity of the case study activity.

It is the opinion of the author that no other research methodology is able to capture a sense of the business in change in the same way longitudinal case study research activity performs this task. The researcher is not simply measuring results or performance statistics, indeed he is delving much deeper into the structure of the business and its interaction with the competition, helping the facility to define, threats, challenges and new competitors and as such the process exposes the challenges that shape future strategy. The depth and breadth of the activity gives the researcher the opportunity to understand the logic and rational of the organisations actions and reactions prior to measuring results and performance metrics. The conclusions that have been drawn from this study aim to reflect this degree of development on-site and throughout the case study business.

6.1 Concluding Remarks

The author has discussed the future possibilities and the state of manufacturing development with key players and change agents throughout the course of the research activity. The most resounding of comments highlights the strategic void that the competitive threat of the low-cost Far Eastern derivative products have exposed, the clear and present danger is universally recognised and is currently questioning the long established paradigms of all of the case studies. They are all significantly impacted by a growing threat at the bottom end of the market from low-cost economy competition, showing no signs of abating. In a number of the case studies, this is perceived to emanate from both internal and external manufacturing competition, and as such has become a significant threat, with several businesses reducing the manufacturing content in the UK over the course of the study. The growth of internal competition has been evident throughout the study period with significant growth of low cost manufacturing facilities attached to each of the case study businesses. Strategically the competitive response mechanism must now be primed to compete in the open market and in the information sharing, open book cost mode of internal competition.

A number of the case studies recognise and comment that one of the main defence strategies for the UK over the next period of industrial development will be a growing need to design, build and deliver products that have been custom manufactured to a distinct customer specification, whilst maintaining volume flexibility and minimising component stockholding and distribution costs. The ability to develop a degree of 'Flexible Agility' whilst maintaining a stringent control of costs will prove to be a

critical survival skill. The general technique has been pioneered by Dell over the last five years, alongside other members of the computer industry, and is now a well established manufacturing norm of the I.T. industry. The Dell concept is also beginning to find fertile ground and grow in other technology-based industries, and the exploration of the concept is considered attractive to all of the case study facilities. No significant examples of Built-To-Order (BTO) or Mass Customisation were witnessed through the case study duration, although all of the case study companies have indicated that this is an area for future development. Although late point identification techniques have not been readily evident in the case studies, all are attracted by the possibility of the Dell technology-based approach to the late point identification of customer-designed products.

None of the participants in the case studies have highlighted elements of or the significant development of "plug and play" modular product systems, as described in recent research literature in the light of knowledge gained from the Dell model. However, all of the case study supply chain management teams noted a desire to actively progress additional supply chain flexibility with the development of web-based systems etc. In the main, the interviewed case study managers feel that at the present time, this will remain a want as opposed to a need in the industries in which they are competing. The author would note that technology is changing at a great speed and highlight the need for each business to monitor the progress of this development area, several of the case study facilities could be considered as falling behind in terms of technology development at the current time. The author considers that the element of the manufacturing system that Dell describe as the "pull-to-order" initiative is an essential element of any BTO (Build To Order) program at Dell,

combining Dell's Lean Systems with advanced computer technology and logistical product forecasting activity. Over the course of discussions with key change agents on this subject differing levels of acceptance were noted and ranged from "I 100% agree with the need for the linked planning technology" to "it's just another gimmick".

A number of statistical techniques were witnessed in the logistical projects reviewed in the course of the case studies, running side-by-side with the more traditional planning systems analysis in the respective supply chain teams, and SS projects like DOE development and reliability Weibull modelling were openly discussed with the teams at case study A and C. The logistic project teams were monitored using tools we might normally expect from engineering and technology departments, although they are not readily and traditionally associated with traditional supply chain improvement projects. The ability to open up the full tool box of skills and fit them to tasks throughout the facility may lead to a more progressive company wide approach to problem solving. The synergy of the two skills bases and development of the dual methodology is a strong attraction to all of the case studies with case studies A, B and C openly moving towards Lean Sigma programmes.

The author discussed with each case study the clash of ideologies that come to the fore from the prime manufacture of volume production, commodity-type products and significant elements of the appeal of world-class manufacturing versus the reality that many B.T.O. organisations produce products in relatively low volumes with significant variety and little or no common components. All of the case study companies were involved in volume manufacture and found the appeal of BTO significant, although they felt that a synthesis approach would possibly be more

suitable to the business in the short to medium term. Case study A are involved in the manufacture and distribution of 416 distinctly different professional power tools that can be ordered in 3,500 differing versions across Europe. The logistics and supply management of case study A indicated a greater interest to progress towards late point identification of volume Far Eastern manufactured product rather than B.T.O. in China. Make-to-Stock manufacturing or mass customisation are two different systems, and significant thought and research is required prior to entering into a program of this nature. Karlson (2002) argues that any form of mass customisation requires a modular product design and assembly concept at the core of the business model. Case A has commenced the development of project activity to adopt a greater degree of Late Point Identification, and the recent consumer adaptor plug project is an example of this activity. The new range of consumer indoor products have a convertible plug that is suited to both UK and European sales, and as such, case A feels that they have eliminated a significant element of potential additional stock-holding, possible obsolescence and product duplication.

A considered list of the key next steps identified by the case study management teams can be defined as follows:

1. **All Case Studies to Consider the New Global Approach to Competition both Internally and Externally and Act Accordingly Ongoing** – focusing upon the subtle nuances of the internal partner and the opportunities to share competitive information throughout the corporation. The open book nature of internal competition focusing on the need to combine world class cost with fit for purpose quality, delivered seamlessly to the global customer base.

2. **The Development of a Form of 'Flexible Agility' Combined with Ruthless Efficiency in All Case Studies** – combining the best approaches of a number of C.I. schools in delivering flexibility to the customer whilst maintaining control of costs and efficiency throughout the manufacturing and distribution value stream. Continually attempting to balance the quandary of true flexibility and performance efficiency with the eventual end result of a strategy delivering optimum balance.

3. **Start to Think Truly Modular in all Product and Systems Design, Now** – prior to B.T.O. the design of the product offering must take on a more modular approach and commence the building block process towards the ability to offer 'plug and play' products. The commencement of a modular approach to products must commence immediately, becoming the foundation of the new manufacturing system.

4. **Consider the Introduction of the Concept of 'Plug and Play' through the Entire System** – the entire systems approach may need to be adapted towards the concept of 'plug and play' and modular design with the adoption of proven logistical and planning techniques adopted from the technology sectors.

5. **Expand the C.I. Tools Usage throughout the Business** – forcing the use of the C.I. tools of Lean Sigma across the entire facility, exposing every department to the opportunities and advantages of the appropriate tools.

6.2 Completion of Aims and Objectives of the Study

In terms of programming the vision the author commenced the research activity with a number of key aims and objectives, the opportunity to search for the corporate C.I. vision ranking highly in the list. Throughout the activity the attempt has been made to objectively review and develop the research process and over the course of the study

continue to learn the intricacies of world class C.I. and explore the tactics that make the programmes tick. The report has been structured to answer the outlined objectives and identify any additional areas of study not covered in the case study analysis. The objectives can be defined as follows, with an outline of the study programs findings included alongside:-

- **Developing a critical mass of knowledge of the industrial development of western manufacturing industry, studying the key development steps in its progression from craft to mass production and onwards to the manufacturing techniques in vogue today.**

The study path followed throughout the research activity commenced with a comprehensive review of the historical developments of the western manufacturing industry in the last century and focused significantly upon the trends reflected from the automotive industry as the epicentre of assembly-based manufacturing. The study of the latest publications and case study findings formed an iterative study process, refreshing the author and adding to the knowledge bank of C.I. information. With the automotive industry forming a core element of the historical academic material available to the author, they can be considered as one of the pathfinder industries that have led the way for manufacturing development in general in the last eight decades. The author focused much of his research upon the parallel development paths of Ford and Toyota to highlight the migration from Mass Production to the concepts of Lean Production in the automotive industry subsequently progressing towards the study of the development of the S.S. in the American multi nationals, Motorola and GE.

The two techniques and the unique tools they are constructed around eventually became synthesised into the emerging concept of the Lean Sigma methodology. The

author has covered the development of the individual themes in the literature review and has attempted to drawn out the key threads from the case studies, documenting various findings and elements considered as important in the conclusions chapter.

- **Plotting the migration path of a UK case study, highlighting its individual development path, commencing with a historical analysis of the organisation and its cultural roots and background.**

The author has documented the migration of a core case study company and three supporting satellite studies of major UK manufacturing facilities, with individual development paths highlighted in each of the studies. Consideration has been given to each individual migration scenario, with a portion of the study devoted to the understanding of the development paths and cultural background that formed the businesses in the UK over the last decade. The author has attempted to highlight the knowledge gleaned along the way and has attempted to critically appraise the approaches taken by the case study businesses and also to include any other anecdotal evidence to support his thought process. The learning's highlighted by the core case study have been discussed with the satellite studies and to some degree enabled them to steer around some of the pit falls discovered by case study A.

- **Studying the individual development trends in place in the core case study and the supporting studies with a view to highlighting the integration of techniques that form the current management continuous improvement plan. Outlining the status quo in force at the moment and critically assessing the current performance metrics.**

The author would reiterate his views on the danger of measuring the improvements externally against a rapidly moving market place, with a number of initiatives reviewed delivering substantial financial rewards, only to be wiped out by low cost

competition changing the game and re-establishing the baseline in terms of products delivered cost to the market. Significantly, a number of the case study businesses had strategic rethinks over the longitudinal study, reflecting the volatile state of global manufacturing's economic picture. The size and magnitude of the emerging threat has convinced several senior management teams to consider deleting the UK as a manufacturing location for there products over the course of the study.

- **Defining the management vision of the future and the step changes identified to achieve this proposed future state, whilst critically assessing the timing and resource plan to deliver the proposed results.**

Each study has highlighted a slightly different management vision for the future, although significant similarities have been found through all the studies. The management teams all agree upon the proposed directional activity required, although individual tactics may vary from business to business. In the main, the manufacturing facilities studied are following similar development paths, with the concepts of Lean Sigma being represented as the new core C.I. activity. The timing and introduction plans differ, though the main thrust in each study remains the same. It is possible to loosely consider that the degree of management attention to C.I. through the case studies reflects and correlates with the perceived degree of competitive pressure they are exposed to. The strategy of C.I. as a defence mechanism against the emerging hordes exposes a vulnerable area of management vision and does not deliver the benefits of the holistic design, development and manufacturing strategy discussed through the findings of the research project.

- **Pulling together the essential and common elements from each case study migration path, whilst understanding the critical success factors in evidence required in the construction of a road map.**

A simple migration path has been plotted for the case studies, alongside an additional element of general review with progressive C.I.-based organisations in the UK. This path can be used in line with the author's L.S. assessment process (Included in Appendix 2.) of the current status of an organisation and the consideration of the next steps of C.I. development in the facility. The assessment tool has been developed from a general Lean assessment tool used in TBM and now also covers areas of S.S. to give an L.S. overview.

6.3 Learning's from the Theory and Methodology of the Case Study Process

The author has attempted to remain neutral throughout the completion of the longitudinal case study analysis process and although the action research element of the study has made this aspect difficult at times throughout the research the author has looked to maintain complete impartiality through the research activity. The academic criticisms of case research are well understood by the author, although as a practical change agent the researcher is unaware of another tool that wields the same degree of powerful incite to the change process. The author considers that the completion of longitudinal research activity is essential to understanding the true nature of change in operations management, and would highlight the excellent vision it has granted to him, enabling him to witness the change agents working in real time in the natural environment of the manufacturing facility. The activity has been founded on the job

site and the interview process has included all levels of employees in each facility, delivering a breadth of findings that can not be compared with numerical analysis of completed questionnaires or reported performance metrics. The ability to evolve the research study as new C.I. techniques emerge, develop and become established highlights the importance of the technique in the field of operations management and the technique should be recommended to any researcher looking to expose cutting edge activity in the research laboratory of the manufacturing world.

Despite the apparent drawbacks of case study research, the author agrees with Voss et al (2002) that this approach can have a significant impact and provide a degree of penetration and insight that is not available to the researcher who adheres rigidly to the imposed limitations of questionnaires. A case study initiative can play a significant part in the unearthing of new theory in operations management, with the longitudinal study highlighting a possible set of process steps by which to successfully perform a study of this nature:

- **The development of a research framework and a research question** – it is proposed that the researcher should approach the framework and question with an iterative mindset and prepare to be flexible in his thought patterns, maintaining objective neutrality whilst being prepared to accept developments through the course of the study.
- **Selection of the case studies** – the case studies selected should, in the author's opinion, allow continued access to the researcher, although prospective researchers should be prepared for many key respondent changes through the course of the activity. The reliance on an individual key respondent may

expose the researcher to unnecessary risk and spreading the reliance across a number of respondents will greatly improve the continuity of the research.

- **Development of a research protocol** – the research protocol should be considered as one of the fixed elements of the longitudinal process and the researcher should attempt to maintain his discipline throughout the study activity. The adherence to the research protocol will ensure a more structured comparison across cases and a higher degree of finding integrity.
- **The approach to the field research conducted in each of the case study organisations** – flexibility and openness are advised in the researcher's approach to the conducting of the field interviews, approaching several levels in each case study to collect multiple levels of feedback and opinions. Then comparing and contrasting the information to evaluate the contrast of the management assessment of progress and the opinion of the workforce.
- **Data collection, documentation and comparison** – the use of an open research framework will make the direct case-to-case comparison of data difficult, and the researcher should approach this phase with this caveat in mind. The researcher should remain committed to good data collection techniques throughout the process even though the observing of case study development may make the case to case comparison difficult to perform.
- **Development and testing of Hypothesis** – the development of the hypothesis and the subsequent testing process should develop organically from the research study and be based on the correlation of findings through the studies.

The researcher has been cognisant of the documented drawbacks of case study research throughout the study and has attempted to eliminate interviewer bias from

the outset. The author feels that it was correct to document his positivist standpoint from the beginning of the research work, although at each of the interviews and site visits he has attempted to remain neutral and unbiased. The researcher undertaking a similar longitudinal study is advised to adopt a similar central position throughout the active participation of the research process. Any numerical data collected by the researcher should be cross-referenced, and attempts should be made to use elements of triangulation in all study comparison activities. The key data identified through the research has subsequently been cross-referenced with multiple means of data collection, from multiple sources if at all possible. The same strategy should be utilised for key manufacturing anecdotes, with the informal story being cross-referenced from a number of differing sources, standpoints and levels in the management and employee structure. The converse activity of scenario-setting can be reviewed in the same way, cross-referencing the resulting answers across the structure and through the management levels to look for common ground or opinion clashes. The use of scenario setting allowing the researcher to pose the same question to several levels of the business without the risk of the respondent feeling as if they are compromising themselves or the case study facility.

An impartial approach is advocated, from the commencement of the study, progressing through the early stages of the study process with a focus upon the impartial development of the research framework. This design should be cross-referenced with other academic advisors in concept form to ensure that an impartial approach is taken from the commencement of the study period. The academic advisor should review the possibility of subconscious bias creeping into the research methodology and reference matrix. It is essential to ensure that all identified areas are

reviewed in each of the case studies, and a tick-box approach is required to ensure that each site visit covers the same ground in an attempt to minimise the possibility of interviewer bias creeping into the research activity or complacency in not covering the predetermined ground. The author's initial interview process and assessment matrix aimed to ensure a consistent and detailed approach was taken at each case study facility and aimed to deliver a constant approach to each site visit and complementary approach to cross case analysis. The matrix had been developed in conjunction with C.I. colleagues in case study A and additionally discussed and reviewed in the construction phase by fellow researchers; this may well have benefited from a greater degree of academic peer review prior to the commencement of the research process. The reference matrix may not have changed substantially, but it is recognised that this activity would have been constructive, and would have aided in the academic discipline of the research.

In line with sound case study theory, a study of seminal authors, such as the work of Yin, is advised, as are critical appraisals of the case study research field. The literature review of the field of study should progress in parallel with the progressive development of the field of case study theory and methodology. The author has given due consideration to Yin's case study tactics for design tests and would advise the student to focus on the construction of his case study material, ultimately concentrating on the internal and external validity of the case material he produces and ensuring throughout the process that the material he has produced is considered reliable. If multi-case replication activities are planned, the researcher must ensure that his structure and framework allows for multiple-case replication and that the

reference framework is broad enough to encompass a holistic view across all of the case studies.

The author advises the researcher to attempt to question the developments observed in the case with regard to both "How" and "Why", and then attempt to apply the knowledge gained to both the building of his theory and its subsequent testing in the later stages of the research. Attempts have been made to highlight the emergence of L.S. as a new continuous improvement initiative, and the search for the causal relationship of the initiatives, has help to outline a proposed development path and a list of implementation guidelines. The author is of the view that the perceived performance improvement of the case studies through the implementation of the various C.I. initiatives justifies the migration activity and commitment of the case study companies. Case study A invested over $1,000,000 developing its training materials corporate wide and the investment could be considered as a substantial commitment. The delivered cost reductions achieved across the corporation highlighting a payback in the first few months of active project work.

The author is in full agreement with Voss et al (2002) that the knowledge development over the period of the research process helps to solidify and structure the research questions in longitudinal case study analysis, and that this highlights the strength of the case study process, allowing for knowledge development and theory building and also allowing a degree of theory-testing on the foundations of theory-building process.

Attempts to secure access to the key respondents of each case study should remain at the core of the case study selection process with the transient nature of the change agents in the field of C.I. mean that a longitudinal analysis focusing upon a single key respondent will be very difficult to complete. All of the case studies featured in the research were impacted by the transient nature of the change agent, with the losses ranging from being head hunted, to commencing a C.I. training consultancy. The author advocates the development of a pool of key respondents and a standard approach towards the assessment of cause and effect and the sequential nature of the events studied that can accommodate the loss of individual key respondents. The author selected unrelated case studies with histories of continuous improvement activity and a tradition of stability with regard to the current manufacturing site. The changes witnessed over the study period could not have been forecast at the commencement of the study, and even case studies with a reputation as leaders in the industrial sectors in which they participate in have had a difficult time accommodating the changes in the UK and European market.

The usage of formal interviewing is recommended as the prime source of case study research data in similar longitudinal studies, including formal interviews with all levels of the management hierarchy and cross-reference activity with the shop floor and other direct areas. The author supports the use of personal observation and general conversations whilst on the shop floor of the case studies and is of the view that if the researcher is able to maintain his neutrality through the study, excellent insights can be gained into the case studies' operating systems. In line with Yin (1994), the author would recommend that researchers focus on the need to develop a

relevant protocol in the case study investigation, and the researcher has attempted to follow a general funnel model for this research process. The author's technique commenced with the development of a series of base foundation questions and expanded and developed into more specific investigation into the use of the tools and techniques of C.I. and the implementation activity on site. The author recognises the need to temper the language and depth of the interview with due regard to the level and knowledge of the interviewee and his exposure to the strategic direction of the case study. The author advocates the need to prepare for the aspect of triangulation within the protocol at the earliest stage, and as suggested by McCutcheon and Meredith (1993), it is advisable to support the key case study with satellite studies to allow for multi-case comparison as an element of the study process. The author concurs with Leonard-Barton (1990) upon the longitudinal nature of the study and the observed developments witnessed in the subject area, feeling that this provided the possibility to develop the protocol from the initial guise of its conception through a process of fine-tuning to ensure that it captured the critical developments at first hand.

In terms of the interview process in the field, the researcher should identify the mutual benefits that the research can bring to the case study manufacturing sites and highlight the positive nature of the learning process to the key respondents and the business in general. The author regards his research process as having had a series of mutual benefits for both parties. The active linking of the case study and multiple key respondents is considered as essential to developing this longitudinal linkage (Voss et al 2002) and ensuring ongoing continuity to the case study. The transient nature of the "change agents" can only be overcome by the development of a company-wide

acceptance of the degree of benefit that the research activity will deliver. The use of the structured interview process can be considered as the author's main approach in each of the studies, with efforts being made to facilitate the response to the C.I. activity from the change agents and the parties affected by the change. The work of Yin (1994), which highlights the skills required to complete field research interviews, is highly recommended. The researcher should take a balanced approach to the differing levels of management interviews conducted, with representation by all levels in the final analysis period.

The author, as the sole interviewer conducting the research, recognises and fully accepts the pros and cons of this technique and commends the longitudinal case study researcher to ensure that all comparable data has been collected and cross-referenced to develop a level of triangulation if this is considered possible. In the research cases reviewed in the present study, significant focus has been placed upon the sequence determination of the evolutionary C.I. process to facilitate the understanding of cause and effect in the identified changes. The use of longitudinal case study research in the field of operations management has some advantages over static survey research in the ability to observe change in the workplace and monitor continuous improvements as they become embedded in manufacturing industries.

The author discovered at an early stage of the research that each of the case studies imposed restrictions on taping interviews and in recording sensitive performance data through the case study period, and as such, has had to use critical appraisal of his interviews after each session to ensure that observer bias is kept to a minimum and that the appropriate level of balance has been applied to the findings. The very nature

of the sensitive material reviewed in the longitudinal C.I. case study will occasionally require a confidentiality agreement to be signed and a degree of sensitivity to be applied to the researcher's findings.

In the use of the case studies as both hypothesis development areas and testing grounds, the researcher should accept at the commencement of the study period that the development of his thesis will prove to be an iterative process. Through the use of replication logic in the studies, the author has aimed at developing hypotheses based upon the correlation and causation witnessed in each of the studies: The author's thoughts on the hypotheses developed throughout the study can be defined as follows:

- **The Introduction of Lean Production Techniques will lead to reduced waste and delivery of increased production efficiencies.**

The hypothesis that Lean Production will lead to reduced waste, can be considered as tested across the case studies and can be considered as proven and supported by a global acceptance of the validity of Lean Production techniques in terms of improving efficiency and driving out waste, with one caveat. The full system deployment of the Lean techniques is essential to exploit all of the available benefits of time-based manufacture. All of the case study reviews conducted feel that the introduction of the tools and techniques of Lean Production reduced waste and increased efficiency. This is dramatically highlighted in the Kaizen breakthrough activities of case study A. The aggregated improvements reflect a 50% floor space reduction, 35% manpower reduction and increased efficiency and output in the region of 30+% on one hundred project based activities.

- **The Introduction of the Six Sigma Initiative will lead to the delivery of significant financial impact through project delivery.**

The hypothesis that S.S. adoption will lead to the delivery of increased financial savings and impact to the business can also be regarded as having been proved across the case studies, and again, is supported by a growing number of converts to the SS school. The author has witnessed significant process-orientated improvements from the use of the S.S. toolbox and considers the 12-step project management process to be an excellent project monitoring and completion tool. The annual audited product and project savings of case study A reflected an average annual benefit of around $6,000,000 through the course of the initiative and prior to the assembly facility moving to the current Eastern European facility. The author would counsel the deployment of the complete S.S. process and the use of all techniques as essential to exploiting the full range of benefits available to any manufacturing facility. Failure to adopt the entire process may deliver a number of local wins, but without the cultural changes delivered by a large-scale acceptance of the benefits of statistical management. Each case study review reported significant project savings by the use of the S.S. tools and techniques.

- **The Synthesis of the two Techniques into Lean Sigma will lead to the delivery of the best elements of both of the initiatives, complementing the business toolbox, reducing waste, increasing efficiency and delivering significant financial bottom line impact.**

The author considers that the two techniques form an excellent synthesis and a complete C.I. toolbox, and would recommend the marriage of the two initiatives. Throughout the case studies and satellite review activity the synthesis of the two techniques was readily evident, with all members of the change process agreeing the

practical benefits gained from the synthesis of the two techniques. The current stance taken by the case studies can be summarised as follows:

Case study A has progressively moved its corporate stance on the initiative name over the course of the study to reflect a growing contribution from the tools of Lean across the corporation and in 2005 openly renamed the corporate wide C.I. initiative Lean Six Sigma. The northern site combined the tools of Lean and S.S. and delivered over $6,000,000 audited annual cost reduction whilst driving the overall plant efficiency performance levels to new heights. Through the course of the study the plant progressed from declared manufacturing efficiency performances in the 80% region to regular performance in the range from 90% / 94%.

Case study B can be considered as granting equal weight to the two initiatives in 2005 and can be regarded as openly intending to follow a development process of Six Sigma integration to the current Lean systems to develop a plant wide Lean Sigma initiative in 2006.

Case study C is openly following a corporate lead Lean Sigma initiative (the Strategic Master Plan) and is committed to the deployment of the initiative as its core C.I. initiative.

Case study D Continues to follow a Lean philosophy, although openly can be considered as accepting the benefit of the two pronged L.S. attack and the group is actively using the tools and processes of S.S. to address process related projects.

6.4 Limitations of the Research

Precision, objectivity and rigor can undoubtedly be delivered by quantitative studies and the case study researcher must attempt to ensure through the discipline of his investigative activities that he also aspires to the same level of professional and academic detail. The key to the delivery of good case study analysis is the understanding of the strengths and weaknesses of the research process and the ability to constantly hold in mind the areas of criticism whilst delivering balanced, objective results. The case study process followed through the course of this research project has highlighted a small number of process limitations that should be considered and understood by the prospective researcher prior to the commencement of a similar longitudinal research project. The key areas of consideration are as follows:

- **Research Commitment** - the very nature of longitudinal study requires a significant degree of personal commitment from the researcher throughout the course of the research project (Appendix 1 covers the researchers process overview). The researcher should consider at length the implications upon his academic and personal life prior to commencing a longitudinal study of this nature. It is appreciated that it will be difficult for the researcher to predict his personal situation and the consequences of any subsequent changes.
- **Free Form Research** - the field of industrial and manufacturing development is a fast-moving and dynamic area of study, and the very nature of the longitudinal research project may well reflect a number of changes to strategy and direction. The researcher is advised to understand this implication at the commencement of the project and to ensure that he has a method of recording and logging the developments and direction of the changes. The active

researcher should consider in advance the fluid nature of case research and appreciate the complexity of the free form research process prior to the commencement of the research activity.

- **Relationship Based Research** - the very nature of the case study process requires the researcher to develop long-term relationships in each study, and an open-minded, outgoing individual who develops relationships easily is best suited to this research process. This research process is not a laboratory or library-based project and the very nature of field research requires highly-tuned communication and listening skills on the part of the researcher. This is not an area for the shrinking violet and many will be the personal relationship set back, slight or snub suffered through the course of the research.
- **Time on the Coal Face** – in several of the case studies the author has operated on the production lines for between one and five days to implement Kaizen or S.S. change activity, commencing with operation duties on a large 1000 tonne press and a automotive exhaust manufacturing line as typical examples.
- **Planning for the Unplanned** - longitudinal studies often highlight changes in business, and as such the researcher will be exposed to areas such as key respondent loss and business decline and downsizing throughout the research activity. The very nature of longitudinal studies require a degree of contingency planning and the ability to overcome set backs throughout the research process. The risk in terms of aborted activity may well be substantially higher than broad based questionnaire focused research or activities that are founded upon existing academic publications and can be considered as centred on secondary research activity.

- **The Problems Associated with the Literature Review Process in Longitudinal Research** - the academic outlook will develop and progress through the course of the study and the literature review should remain a live document from commencement to completion of the study process. The literature review will not be a chapter for completion in the early stages of the project: it will evolve alongside the case studies, and the researcher is advised to review the literature of the subject areas in parallel with the case study analysis. The author commenced a significant literature review in the early stages to establish his knowledge base in the area and regularly returned to the latest publications and academic thinking in his subject area to stay in touch with the cutting edge in C.I. and operations management research. Failure to stay in touch with the latest findings will expose the researcher through the later stages of the project and may significantly weaken the integrity of the activity and its findings.
- **The use of Confidential and Sensitive Material Discovered in the Case Study Analysis** - much of the material identified within the case study process, working alongside "Blue Chip" manufacturing companies, is likely to be confidential, and any sensitive material should be discussed with the case study management team or the key respondent. If the author has any doubts upon the sensitive nature of the case study material, the material should be excluded from the formal report even if a key respondent has agreed to its publication. The case study researcher may not have the opportunity to test sensitive material with a wide enough audience in the case study business and as such playing safe will be the best policy. Material may not be considered as

sensitive to the manufacturing location, but could be considered as highly sensitive by the head office or another facility in the corporation.

- **Prepare for Mantraps** - the author would recommend the researcher to tread carefully whilst on the site of any case study facility and be aware of any political implications behind the answers the researcher may receive or the leading nature of any questions he may be asked. All of the case study facilities downsized or closed in the course of the study period, and significant job cuts were witnessed though the research process.

The very nature of the longitudinal case research process requires a flexible open minded approach to research combined with an inquisitive mind and the ability to overcome a continual flow of issues and interruptions. The researcher may benefit from a hands on action based approach to gain the most from the activity process, contributing to both the C.I. development in the case study and the researchers own educational development.

6.5 Recommendations for Further Research

The subject area of Lean Sigma development is a ripe area for additional research and many questions at this current moment remain to be answered. This thesis explores the development of Lean Sigma from the embryonic roots of Lean and T.Q.M. to the current day Lean Sigma C.I. solutions, with the research highlighting a significant number of opportunities for further exploration, as follows:

- **The development of Lean Sigma in Small and Medium sized enterprises (SME)** – the initial acceptance of the process of L.S. has been pioneered in the

main by large multinational businesses with significant training and system development resources focused upon the roll out activity. The introduction of the L.S. techniques in the SME's of the UK may require a different approach and may well be less holistic in its initial introduction activity and launch approach. The research activity may monitor the resources required to deliver the program and the time scales required to launch the activity in an SME.

- **Techniques for the deployment of L.S. in an SME environment** – the support for the rollout process in an SME may require a rethink in the material development and deployment, possibly using a commercially available package and excluding the use of expensive external consultants. The research activity could focus upon the assessment of the success of the introduction process, collecting the detail required to compare the SME process against a launch activity in a large multi-national facility. The condensed nature of the program inside the SME with the use of public domain material for both teaching the tools and techniques and also for project monitoring purposes, may also expose an opportunity to directly measure the delivered results (In $'s) in terms of Black and Green belts trained against a more bespoke large scale roll out program in a multi national.
- **Long term performance analysis in an established L.S. facility** – the opportunities for a long term assessment of success in an established L.S. environment are currently limited by the degree of penetration and the relatively short time scales of the current converts. This area will form a fertile research ground in the future with a number of UK facilities now two or more years into the use of the L.S. initiative. The research activity in this project has

focused upon the embryonic growth and establishment of the process and the time may well be right to focus on the delivered results in subsequent years.

- **Any problems associated with the continual usage of annual L.S. assessment tools such as Cost of Failure analysis** – with much of the L.S. roll out initiative being based upon annual assessment tools such as Cost of Failure review, a solid financial record will be available in many case study facilities exposing the success factors or difficulties of the ongoing usage of such an assessment tool. The author has had significant success with the tool as a launch initiative or yearly review process in the first phase of L.S. the next phase of assessment may focus upon the ability to continue focused upon Cost of Failure type assessment in the later stages of the initiative.
- **The development of initiative fatigue in a L.S. business** – through the review of metrics such as project completion records, financial savings recorded and the Cost of Failure assessment alongside structured interviews and employee reaction the identification of initiative fatigue may well be possible. It may also be possible for the research student to correlate the reduction in delivered project savings with an increasing feeling of initiative fatigue inside of the facility. The opportunity value of projects may diminish over time and this could lead to the dissatisfaction of the project leaders.
- **Opportunities to rejuvenate the L.S. initiative in a flagging facility** - through the use of a case study process it may be possible to assess the critical success factors required to rejuvenate a facility with a flagging L.S. initiative, the development of a set of re-launch guidelines may well be the deliverable.
- **Staff retention issues in a leading L.S. business** – the research completed by the author exposes a significant issue with the retention of change agents and

highly skilled C.I. managers. This area is very topical and could provide a significant contribution to knowledge in operations management. The researcher could look to plot the correlation between the levels of C.I. knowledge in a change agent and his market price, and triangulate his findings, via cross referencing the delivered project savings of the individuals.

- **Knowledge transfer over time in a L.S. facility** – the ability to expand the knowledge base of the individual can be defined as a core element of the L.S. roll out process in the early stages of training. This active gathering of knowledge over time being gradually replaced by a plant wide knowledge transfer process as the initiative reaches maturity. The success or failure of this element of the roll out plan will be key to the success of the total initiative, the researcher may be able to plot the separate phases of knowledge transfer and establish a set of guiding principles to run in parallel with the roll out plan.

The growth of the LS initiative across the industrial facilities of Western Europe can be considered as picking up pace, moving on from the early innovators and into the manufacturing mainstream. The progress of the Lean Sigma initiative will expose many significant opportunities for additional study and research and prove to be a ripe area for the students of operations management in the future.

This longitudinal case study research process has exposed many areas ready for detailed quantitative analysis and assessment and hopefully given the next generation of research students a historical view of the C.I. development path taken by many facilities in the UK. The question remains will the initiative work in the long term as the pressure of competition increases.

6.6 Reflection on the Research Process

The research and development of this thesis can be considered as a staging post on a personal journey I have had the pleasure to walk over the last twenty years. The path has not always been an easy way to follow and on numerous occasions I have approached a cross roads and decided upon the less well trodden direction, some times looking for a short cut that I never realised, some times diverging from the more commonly trampled road, thorough a desire to find a new way. I discovered the Continuous Improvement work of the early Total Quality practitioners and gradually became hooked upon the refreshingly simple culture of doing things "right first time" every time. This working methodology looked to be in stark contrast from the pile them high sell them cheap mentality I was familiar with. I was not sure of the destination of the new path I was following but I knew the direction I was heading was instinctively correct.

Maps were replaced by seminal works, such as 'The Machine that Changed the World' and 'Lean Thinking' further convincing me of the road ahead, I now ran faster than ever approaching the next cross roads to find two paths diverging. The road to Lean lay to my left and the path to Six Sigma to my right. My first instinct was to leave both paths and find a middle way, this direction looked to be lightly trod and full of problems, it would prove to be the correct direction for me despite the pull of the fundamentalists that preached the need to choose one of the more established paths. The middle way is now well established, I feel proud of the small part I have played in the establishment of this path.

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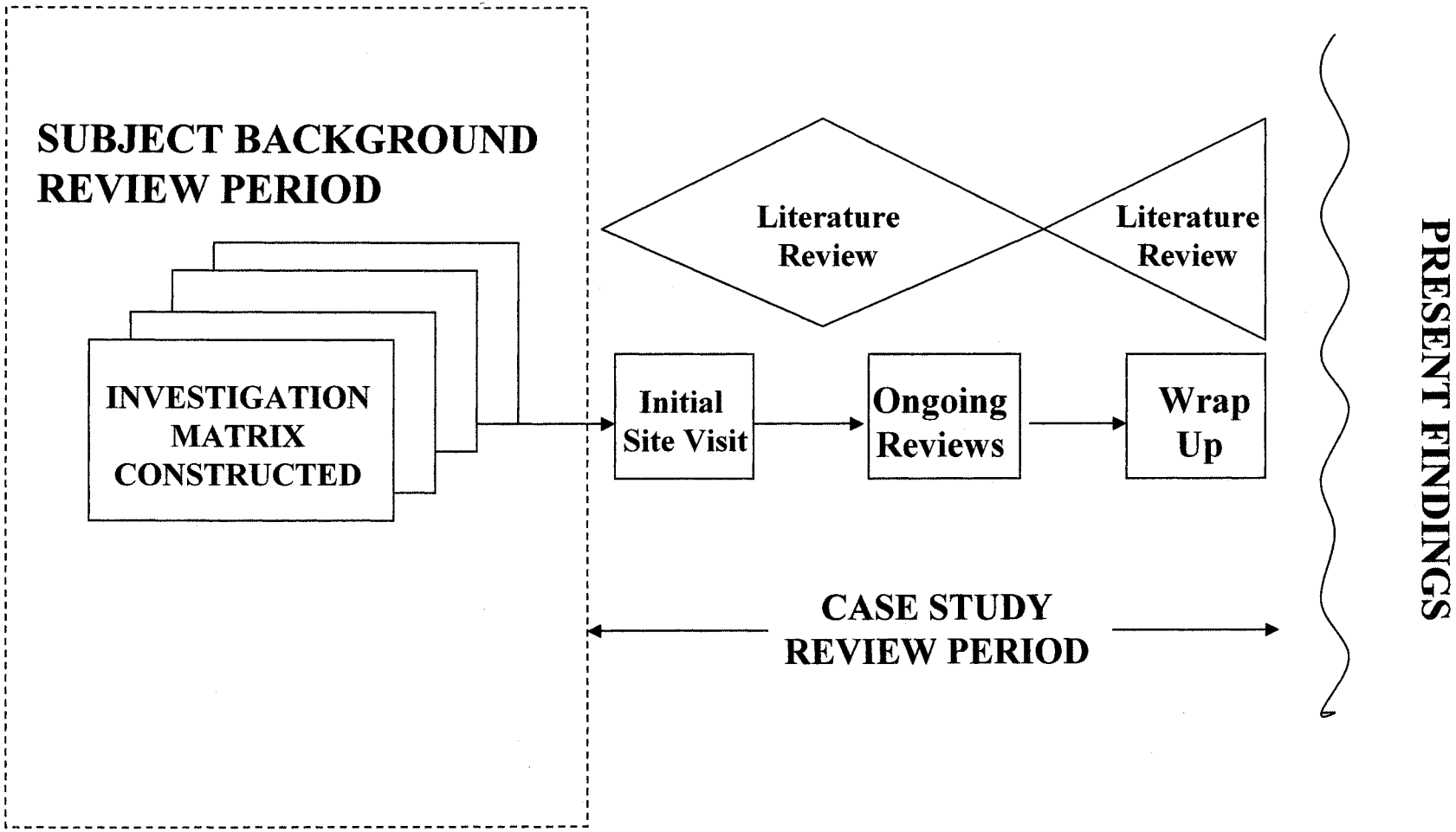
Appendix 2. - LEAN SIGMA PROGRESSION ASSESSMENT CHECKLIST

Circle one description for each category: Name Date

	Level / Category	1	2	3	Score	Comments
JIT	**Takt time**	T/T unknown	T/T known but not achieved	Optimum productivity at T/T		
	Process flow	Job shop	Isolated islands	Integration		
	Material flow	Pallets, skids	Single box	1 set		
	Pull	MRP Launch (push)	Pull within plant	Build based on customer demand		
	Standard Op.'s	Unidentified	Defined but not used	Reviewed & Kaizend frequently		
	Setup Reduction	Greater than 30 minutes	10 minutes	Within T/T		
	Material Replenishment	Large batch, variable delivery	Organised part store area	Deliver 1 set direct to line		
Jidoka	**Detection (Quality)**	Unknown / Undetected	Manually detect	Prediction of problems		
	Autonomation (Productivity)	1 Person 1 Machine	Auto process, auto return	Load – load		
Production Smoothing	**Production planning**	React & expedite daily	Reliable weekly schedule	Reliable monthly schedule		
	Visual Control	No visual controls	Some measures, no reaction	Plant-wide & aligned		
	Multi-processing associates	1 Person 1 Process	Some ability to rotate within line	Unified program, but not being sustained		
	Continuous Improvement culture	No program	Program in place, but not unified(flavor of the month)	All employees accountable for program		
	Project Selection Tools In Place	No Project selection In place	Some analysis performed in selection	COF process linked to business objectives		
	Measurement System Analysis	No process of measurement system review	GRR performed as and when	Continuous analysis & GRR process		
	Basic Statistical Tools in Place	No statistical tools in place	Some use of basic analysis tools	N/A		
	Control & advanced Techniques in Place	N/A	N/A	Full use of statistical and DOE tools inc, control tools		
	Financial Review Post Project	No analysis post project completion	Review Performed on some projects	All Projects reviewed post project		



Appendix 1. – Research Process Overview