Mass customisation procedures in engine assembly

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MASS CUSTOMISATION PROCEDURES IN ENGINE ASSEMBLY

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By

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Cummins Engines

ABSTRACT

The implementation of mass customisation into a manufacturing environment is by no means an easy task to achieve. This thesis will attempt to investigate the areas within a manufacturing company that require change in order to be integrated into a mass customised environment. The hypothesis behind the research is that all aspects of mass customisation in manufacturing can be brought together in a framework for the implementation of new products into a mass customised organisation.

Two major case study investigations were undertaken at a diesel engine manufacturing company, Cummins Engines, at their Darlington Engine Plant to observe current practices for new product introduction and identify opportunities for improvement through tailoring the procedures towards a mass customised environment. An objective of the research was to understand the inter-relationships between processes and departmental structures. Recommendations for possible improvements in processes, procedures and practices in mass customisation framework are included, with a particular focus on new product introduction.

The work carried out within the thesis will look at what inputs are required within a new product introduction programme in order to get the desired outputs. The typical inputs will include the relationships between different departments within an organisation and what is required in order to introduce a mass customised product.

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NOMENCLATURE

DEP	Darlington engine plant
VPI	Value package introduction
OEM	Original equipment manufacturer
SFP	Strategic facilities plan
AIP	Assembly initiated production
HFAA	Hyper flexible automatic assembly
FPA	Functional process area
TQM	Total quality management
JIT	Just-in-time
WCM	World class manufacturing
MS	Manufacturing strategy
SE	Simultaneous Engineering
DFA	Design for assembly
DPD	Design process development
DFM	Design for manufacturing
DFEE	Design for existing environment
NPI	New product introduction
FMP	Fractal manufacturing partnerships
QFD	Quality functional deployment
HOQ	House of quality
TPM	Total preventative maintenance
EEA	European engine alliance
ASB	Agricultural structural B series
TDC	Top dead centre
IPV	In-process-verification
PPEPD	People per engine per day
DFSS	Design for Six Sigma
CNN	Cable News Network
ROI	Return On Investment

Chapter One: Introduction

1.0 Overview

In an industrial environment, it is necessary to satisfy a customer's needs and expectations in order to gain market share and survive in what can be an extremely competitive market. Mass customisation can be described as 'the aim to satisfy individual customer needs while keeping mass production efficiency' and can therefore be used to meet the above criteria. Traditionally, concurrent engineering has been considered as one of the most effective approaches to reducing product development lead times and achieving overall cost savings.

This thesis will investigate the theoretical aspects of mass customisation and the strategies that may be required in order to develop a successful framework for new product introduction into an existing manufacturing environment. The case studies that will be used are from a diesel engine manufacturer who operates under a mass customisation strategy. The new product introduction strategies will be observed and evaluated in order to test the mass customisation framework.

There are many different strategies that are undertaken by different industries, some of which will be investigated in order to understand their suitability for mass customisation. These are as follows:

- Facilities planning for mass customisation
- Assembly initiated production
- Green manufacturing
- Simultaneous Engineering
- Design for manufacturing and product design development
- Agile manufacturing
- Fractal manufacturing partnerships
- Adaptable production

The aims and objectives of the thesis can be shown in **Figure 1.1**

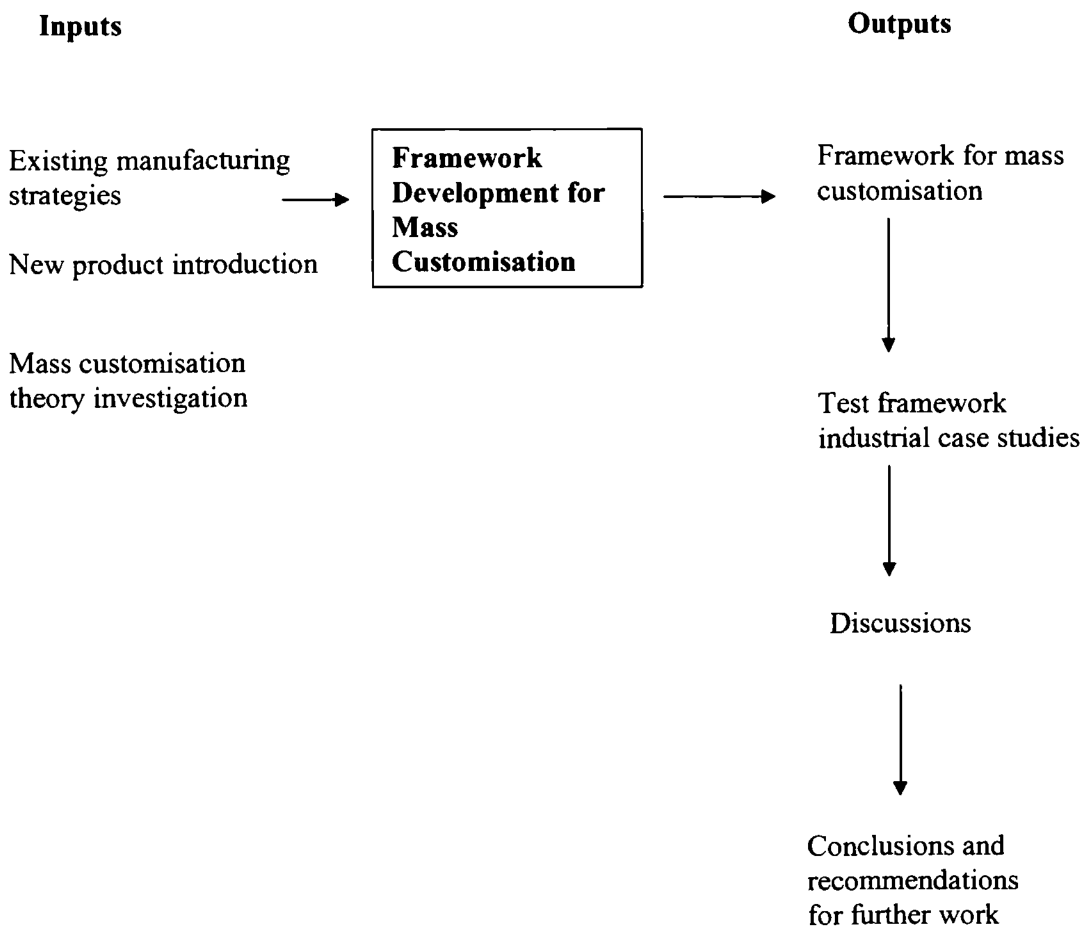


Figure 1.1 Flow diagram of new product introduction

1.1 Aims

To provide an answer to the question 'how does mass customisation impact the new product introduction process? To do this it will be necessary to gain an understanding of mass customisation and what is required to achieve it within a manufacturing environment. This will include an ability to demonstrate the inter-relationships between new product introduction and Mass customisation.

As part of this work, it will be necessary to create a novel framework for developing mass customisation strategies within manufacturing organisations and investigate existing manufacturing strategies and compare their suitability for Mass customisation.

1.2Objectives

(i) To gain an understanding of what Mass customisation is and existing manufacturing strategies

(ii) To identify the product-based factors that affect Mass customisation

(iii) To identify the environmental factors that influence Mass customisation

(iv) To identify the inter-relationships between product based and environmental considerations

(v) To develop a framework for Mass customisation in engine assembly.

1.3Background

Cummins is an American multinational company who produce engines for many applications throughout the world. They employ 24,000 personnel worldwide. Founded in the 1800's, Cummins have become the world's largest independent manufacturer of diesel engines of 150Kw and above. Cummins is a major supplier of diesel engines used in the following applications: - automotive, agriculture, rail, defence, construction, power generation and marine.

In Europe alone, Cummins is estimated to have built approximately three quarters of a million engines in the last 35 years. They have manufacturing plants in Great Britain, USA, Brazil and Mexico, with joint venture / licenses in many parts of the world. The company policy is to build quality into the product from the drawing board and at every stage of manufacturing. A quality systems program was introduced, which ensures that marketing, engineering and manufacturing functions work together to ensure that customer's needs are met and quality improvements achieved.

Cummins employs over 5,000 people in the central area (Europe, the Middle-East and Africa). There are two engine assembly plants in Britain located at Daventry and Darlington. In addition, they have a parts distribution centre in Belgium, wholly owned distributorships in the UK, France, Germany, Italy, Turkey, South Africa, Zimbabwe and offices in London, Moscow and Algiers.

Cummins components group of companies is represented in Europe by Holset Engineering Co. who manufactures Turbochargers, Industrial couplings and crankshaft vibration dampers at Huddersfield and Halifax. The dampers are also manufactured at Lyon in France, Dresden in Germany and Barcelona in Spain.

1.4Darlington Site.

Darlington Engine Plant, see above, was established in 1965 and constitutes an investment well in excess of £40 million. Current aspects of business include the assembly of B and C series engines on C and D skids. In 1993 the 1 millionth (B+C) series engine was produced from Cummins plants worldwide.

The Darlington sites major markets include the UK, Europe, The Far East, Brazil, China and Korea. The engine plant itself covers an area of 252,000 square feet and there are currently around 750 employees at the Darlington site. This includes the hosted central departments; Finance, Human Resources, Manufacturing Support, Supply, European Technical Operations and some marketing groups as shown in **Figure 1.2**. Up-fit of Heavy Duty product is also a significant part of the Darlington operation. It has three Queen's awards for export achievement and has many quality approval awards including BS EN ISO 14001.

Mid-range Assembly Business Structure by Department

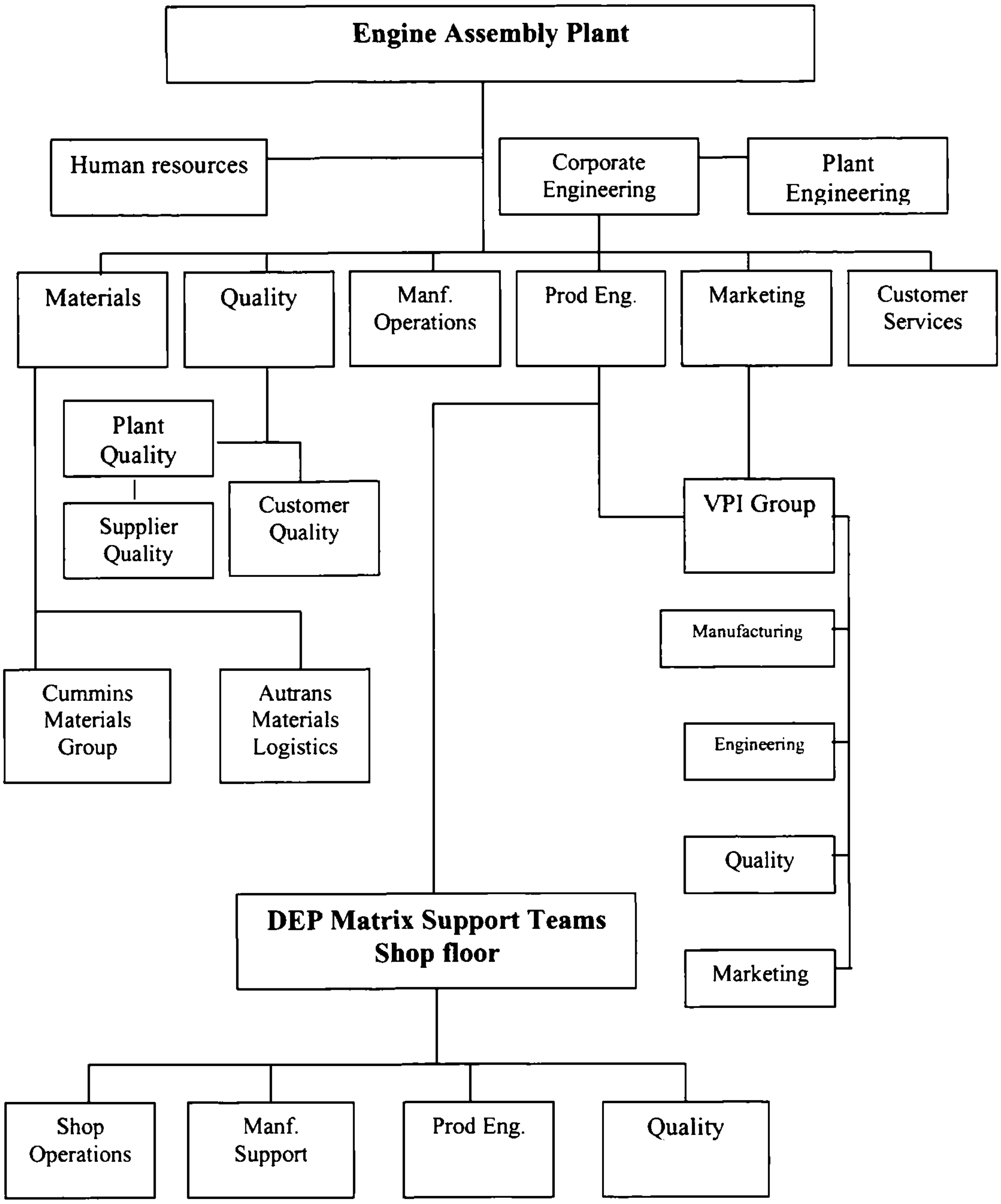


Figure 1.2 Mid-range Assembly Business Structure

1.5The Value Package Introduction (VPI) Group

The VPI group are mostly involved in new product introduction and work closely with the Marketing accounts group to identify new products opportunities and implement them. There is a cross-functional team that works with the VPI group to ensure that the plant is capable and fully equipped for any manufacturing change. The core team is shown in **Figure 1.3**

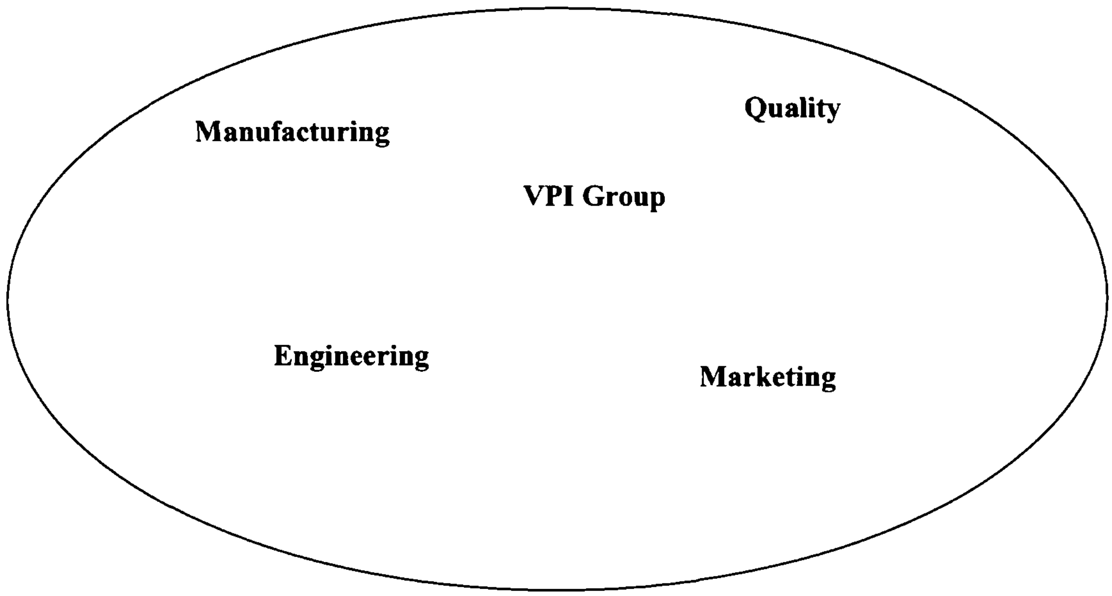


Figure 1.3 VPI Core Team

1.6Matrix teams

The matrix team's function is to directly support the shop floor activity. This is a cross-functional team strategically positioned in the centre of the Production area. The advantage of this is to enable a rapid response to all manufacturing, quality and engineering issues.

1.7COS – Cummins Operating System

Cummins has a top level operating strategy that is designed to guide the whole Corporation in key areas of the business. These are known as the ten COS practices and Are detailed below;

- Put the customer first and provide real value
- Synchronise flows (material, physical and information)

- Design Quality into every step of the process
- Involve people and promote teamwork
- Ensure that equipment and tools are available and capable
- Create functional excellence
- Establish the right environment
- Treat suppliers as partners
- Follow common problem solving techniques
- Six Sigma – a primary process improvement method

It will be necessary to test this strategy to investigate its relevance in a case study and to compare the actual findings with the theory discussed in appendix 1. The planned work is illustrated in Figure 1.6

COS Theory	To understand the theoretical underpinnings that forms the manufacturing strategy for each product introduction
Case Studies on real manufacturing projects	Analyse case studies from 'real' manufacturing projects – what lessons can be learned and what important factors can be included in the framework
Test theory against actual findings	Be able to demonstrate that the framework can operate in a 'real' environment.
Conclusions	Evaluate the frameworks effectiveness. Have all objectives been met? What has been learned for future mass customisation product introductions?

Figure 1.6 Flow Chart of Planned Work

Chapter Two: Literature Review

2.0 Aims

This chapter surveys the available literature to gain an understanding of what mass customisation is and investigate existing manufacturing strategies. There is a requirement to research literature and various manufacturing related themes to gain an understanding of where a mass customisation framework might fit within a manufacturing environment. The scope of this literature review includes the four pillars of mass customisation, green manufacturing, agile manufacturing, simultaneous engineering and lean manufacturing.

2.1 Introduction to Mass Customisation

2.1.1 Economic Justification for Mass Customisation

Mass customisation can be defined as 'the aim to satisfy individual customer needs while keeping mass production efficiency.' Concurrent Engineering has been considered as one of the most effective approaches to reducing product development lead times and achieving overall cost savings. However, recent trends of increasing product variety, primarily due to the growing areas of self-expression and the explosive expansion of global markets, pose a challenge to the traditional Concurrent Engineering agenda. Manufacturers often have to struggle with the trade off between time to market, product variety, and mass efficiency. The symptom manifests itself an emerging engineering paradigm, namely mass production efficiency Pine (1993).

Mass customisation embarks a new paradigm for manufacturing industries. It recognises each customer as an individual and provides each of them with attractive tailor made features that can only be offered in the pre-industrial craft system. In the mean time, its customers can afford the products because mass production enables low cost. Thus with mass customisation, companies can outpace their competitors in gaining new customers and achieving higher margins Hart (1994). This forms the basis for the economic and financial justification when employing a mass-customised strategy.

In high volume production, the volume is sufficient to defray the cost of investment in equipment, tooling, engineering, training and others. Mass production clearly shows an advantage. However, in low to medium volume production, where production quantity cannot justify and leverage the investment, customers are otherwise willing to pay more because their special needs are satisfied. This is the area where mass customisation provides a tremendous advantage in competition.

This is shown in **Figure 2.1** Tseng and Jiao (1996).

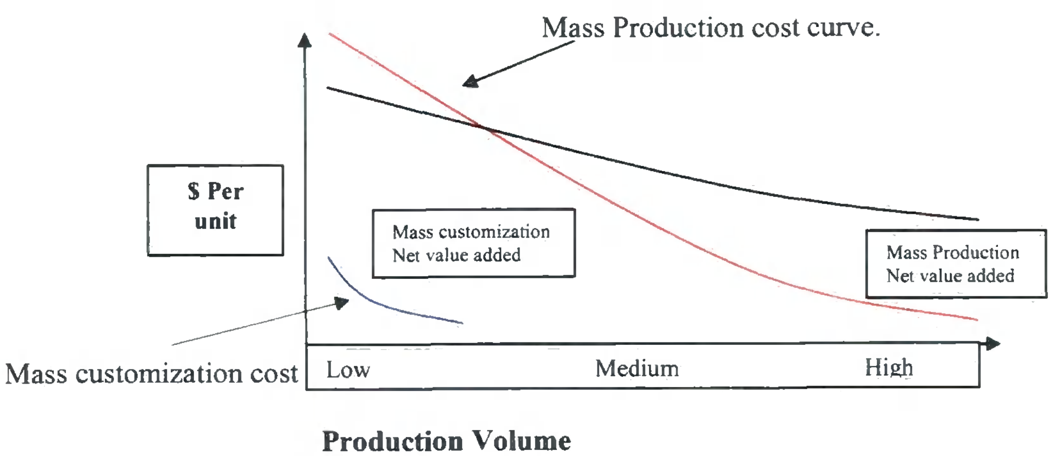


Figure 2.1 Mass Production Cost Curve.

2.1.2 Practical Implications of Mass Customisation

Mass customisation raises many implications for theory development and testing across a broad horizon and subsumes many recent trends in manufacturing flexibility (greater variety and responsiveness to customers) consequently it has drawn the criticism that it has the look and feel of a revolutionary paradigm, without a coherent framework, it remains a re-packaging of many ideas found in the manufacturing literature, with only limited synthesis.

Moreover, competitive strategies in the 1990's include diverse and related themes such as manufacturing flexibility, time based competition, lean production, re-engineering and continuous improvement. The structure and infrastructure issues are critical to the successful implementation of mass customisation with respect to the compatibility and balance with various strategies and technologies Lau (1999). As a result it is imperative to develop a coherent framework with systematic approaches to enable the realisation of mass customisation.

There is nothing simple about mass customisation, it cannot be described as a simple strategy to be undertaken by an organisation, nor is it a simple concept to comprehend. There are two definitions that can be used to understand mass customisation, the first is the visionary definition: 'the ability you provide your customers with anything they want it, anywhere they want it, and any way they want it' Hart (1994). This is extremely difficult to achieve, even by those companies whom are focused and committed to becoming world class customisers, It is therefore a more practical definition: 'the use of flexible processes and organisational structures to produce varied and often individually customised products and services at the low cost of a standardized, mass production system' was provided by Hart (1994). The products and services referred to in the second definition are not unrealistic as 'anything at anytime' as described in the visionary definition. The focus is to ascertain, from a customers perspective, the way in which a given product or service can be meaningfully customised.

Luton Electronics Company is a good example where products such as lighting controls are customised to individual specifications. These customisations can include colour and system integration Pine (1993).

The ability to produce customised products as requested by the OEM, with very short cycle times and mass production efficiencies is a far more realistic definition.

A second example from a non-manufacturing entity involved in the culture of customisation is Ted Turners vision or the Cable News Network (CNN) started in 1980. CNN was envisaged as a cable news service that would be available to everyone, whenever they wanted it (24 hours a day), whichever way they wanted it (on cable networks across the world) and to a lesser degree, how they wanted it (consumers can choose between in depth CNN news or headline news, which cycles through news, weather, sports and entertainment every half hour).

As telecommunications technology advances, it is not inconceivable or inconsistent with Turners view that CNN will eventually be able to search the load of raw news stories for those that match a predetermined customer profile and then download them directly into customer's television sets. Indeed several publishers already offer customised magazines and newspapers to their subscribers Pine (1993).

2.1.3 Why is there Mass Customisation?

In today's business environment, ongoing systematic changes within companies are mandatory. There are many reasons for this, but the most important one is the 'breakdown of the stable mass market of yesterday, the mass market that gave birth to the concept and system of mass production in the first place' Davis (1987).

The result of this breakdown is that not only are customers harder to generalise, with homogeneous markets increasingly a thing of the past, but also the individual wants and needs of any one customer are more and more prone to changes and shifts. Mass-market breakdown has been further abetted by technology. Product life cycles become shorter and shorter, while keeping up with technology change has been difficult for both manufacturers and customers. Mass customisation, as an organisational strategy, is arising in direct response to the turbulence that has splintered the mass market.

A company fully committed to mass customisation, on the other hand, considers the unpredictable nature of the market place, an opportunity rather than an inconvenience or threat from which to retreat.

2.2The Four Pillars.

According to Hart (1994) true commitment to mass customisation requires an explicit mass customisation strategy. An explicit mass customisation strategy is unique to a company and will require them to develop and implement it. A framework is required that guides companies in the development of a unique strategy, as it is not possible to copy an existing organisations methods.

Hart (1994) proposed a method that can be used in order to aid a company in the development of a mass customisation strategy called the four pillars shown in **Figure 2.2**. This can be used to evaluate the strength of a strategy as described in the following sections.

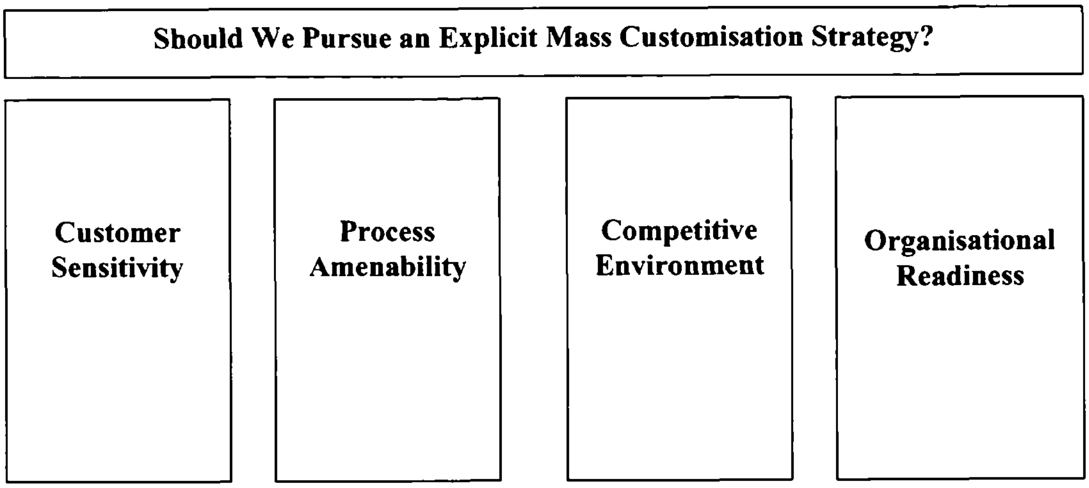


Figure 2.2 The Four Pillars of Mass Customisation.

2.2.1 Customer Customisation Sensitivity

Customers are ever more demanding for affordable products. What needs to be determined is whether the customer cares about customisation. If not then the potential may be limited, and there is no requirement to invest in such a strategy.

Customer sensitivity can be based on either of two factors. These are;

- The uniqueness of the customer's needs
- Customer sacrifice i.e. inconveniences, high cost, difficulty in ordering, service deficiencies Reichheld *et al* (1980).

A high level of unique needs and customer sacrifices will produce a high customisation sensitivity level. If the above matches the companies' current status, then there is a customer base that has major unmet requirements and one that constitutes a strong first pillar Hart (1994).

When considering customer sensitivity and mass customisation, it will be important not to overwhelm the customer with choices or options. A good example of this would be where automotive manufacturers offer complex arrays of steering wheel and hubcap designs Reichheld *et al* (1980). These may not be considered as being particularly important to the average customer. It will be important to design a product or service option that customers truly care about and ensure that these areas have the largest envelope of variety.

2.2.2 Process Amenability.

According to Hart (1994) this is a multi functional area and involves marketing and strategy, design, production and distribution. This can be split into two categories: technology based and organisational, without the technologies to analyse the customer's individual needs and to be able to target products or services, mass customisation would be extremely difficult – if not impossible.

The design aspect of process amenability requires the design team within the organisation to have access to information concerning individual needs Pine (1994). It will also be necessary for the company to be able to translate the customer's needs into the product, with a 'quick-to-market' process.

Production issues are the fourth area of the pillar. How flexible is the system to cater for mass customised products? What is the time required to receive specialized parts from the supplier and deliver to the customer. Does this require the building of inventories of standardized products rather than building products to order?

The organisational enabler is where an individual employee has responsibility for all related tasks associated with a particular customer transaction Davis (1997).

Organisationally, it is important for the marketing department to have access to a sufficient level of detail regarding customer needs for mass customisation. A great deal of one-to-one customer / supplier interaction is required and to build up a positive collaboration.

2.2.3 Competitive Environment.

When implementing mass customisation, it is important for the company to consider the following question. 'Are there competitive forces that would enhance or detract from the advantage the company would gain from implementing mass customisation'? Reichheld. *et al* (1980).

There are many different factors that need to be considered, the first of which is economic uncertainty and the impact this can have on the organisation? The second is the company credibility and its position in the market place. Other marketing related questions that should be considered are 'What is the new potential for new competitors and existing customers alike?'

2.2.4 Organisational readiness.

Any company wishing to undertake mass customisation will most definitely need to consider organisational readiness. It requires assessment on both organisational culture and resources. The strategies must exhibit a good awareness of all areas of the corporate value chain that are relative to achieving the mass customisation goal Hart (1994).

It will be the jobs of the corporate leaders to assess the monetary costs required to pursue an aggressive mass customisation strategy Pine (1994). The company must then be in a position to fund it.

2.2.5 A Summary of the Four Pillars

The most important mass customisation prerequisite is the understanding that mass customisation itself, is a highly customised strategy. You cannot implement another company's mass customisation strategy. At every level, mass customisation must be customised to the organisations needs, customers, production capabilities, competitive situation, and the new technology available to you. Mass customisation is not a generic manufacturing strategy and any company truly prepared for the effort that implementing this profound new strategic goal entails will be significantly rewarded in terms of customer loyalty, market leadership, productivity and profitability.

2.3 Chronology of production

In order to understand what is required in mass customisation, it is first necessary to study the chronology of production to understand the history of different strategies. This will give a firm foundation from which to build.There have been many shifts of change in manufacturing throughout the years. It is important to understand the fundamental developments that have taken place Smith (1992) and Womack *et al* (1991) have broken down each paradigm. These are as follows:

- *Craft production* – is the phase in which craftsmen contracted and completed individual projects on a job-by-job basis. Consumer requests were mostly for new products, which varied from a previously manufactured item
- *Mass production* – Perhaps the best example of this is that of Henry Ford's mass production line, where identical products were rolled off at the end of the process as quick as possible. Throughout mass producing companies, product variety was minimal but increased somewhat as time progressed

- *Lean /Just-in-time (JIT) production* – this manufacturing paradigm uses the principles of mass production and integrates them with the principles of JIT and elimination of waste in order to minimise the total cost of producing a product.

Each paradigm has been used throughout the manufacturing world. The Europeans mainly dominated craft production. The Americans pursued the mass production strategy and the lean / JIT production has been mastered and dominated by the Japanese.

Lean production is described so because it uses less of everything compared to the other paradigms mentioned. *Wibberley* (1993) highlights that a study of the automotive industry showed that lean producers have a significant advantage over mass producers in every aspect of production systems.

Lean production also requires keeping less than half the required inventory on site, results in fewer defects and produces an ever-growing variety of products Womack *et al* (1991). With each manufacturing phase shift, the countries who have first implemented the new phase, have reaped the rewards of their first to market advantages, while those who have refused to accept change have been left behind.

It is possible to provide a comparison of industry objectives for craft, mass, lean and agile manufacturing. The table below shows that agile manufacturing looks to optimise the elimination of waste and the sensitivity to customers and other industry objectives. The other paradigms did not achieve this in their organisation Amir (2001).

Industry Objectives	Craft Production	Mass Production	Lean Production	Agile Production
Emphasis on elimination of waste	Medium	Low	High	High
Degree of production levelling	Low	Medium / High	High	Flexible
Degree of organisational communication	High	Low	High	High
Sensitivity to customer demands	High	Low	Medium	High
Need for skilled employees	High	Low	Medium	High
Degree of cooperation between employees	Medium	Low	Low	High
Piece cost of small runs relative to large runs	Same	High	Medium	Same
Product lead times	Varies	Short	Short	Short

Figure 2.3 Production strategies through time

It will be important to measure mass customisation against the above industry objectives, as this will help to generate an overall profile of what mass customisation is, and what procedures should be put in place to make it successful. Mass customisation can then be compared to the other paradigms as listed above in figure 2.3.

2.4 Facilities Planning for Mass Customisation

Facilities planning should be strongly linked to the manufacturing strategy that an organisation takes. There are a number of questions that should be considered when doing this. These are accurately constructed by *Wrennall* (1996):

1 Does the company still have a functional organisation mind set?

2 Is the company trying to increase the accuracy of forecasting for its operation plans?

3 Has the company the necessary skills and knowledge needed to make the new products and operate the new process?

4 Is the company leading or following, pushing or pulling, or is it focused?

5 Is there consistency between the strategic intent and what is happening in the organisation?

By considering the above, the company is determining a Strategic Facilities Plan (*SFP*). This is where the company strategy is identified, the site mission and operating strategy is decided and lean processes and designs integrated to support the business strategy. Figure 3 shows this in a diagrammatical format.

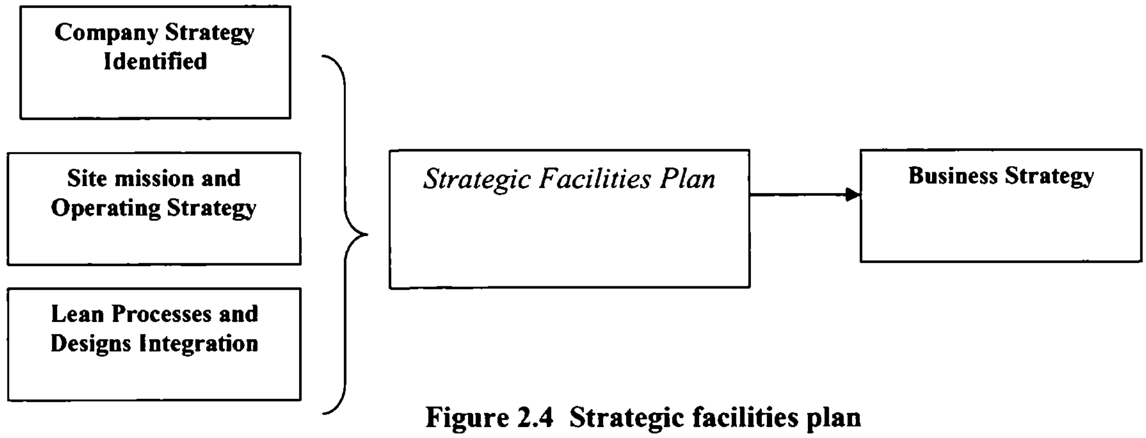


Figure 2.4 Strategic facilities plan

Identification of Company Strategy

This will be derived from the top level of management from the organisation and will have a direct link into the SFP.

Site mission and operating strategy

This can include the assembly strategy and deals with issues such as the TAKT time (a German word for pace) i.e. the rate at which the customer requires the product Hammer *et al* (1993). The headcount required to run efficient operations, the return on investment etc.

Lean processes and design integration

This can include things like pull systems – a strategy in operations where the requirements of a step or stage in an operation "pulls" the material only when it is required to perform the assembly. These can reduce the complexity of the system and are elements of lean operations

Another tool that can be used in lean processes is Six Sigma as applied in Cummins, where a statistical measure of the capability of a process and its ability to perform no more than 3.4 defects per million opportunities.

In addition to these, there are various constraints that will affect the design integration. The physical constraints are of course important with issues such as the building size, number of floors, space available, columns and doorways etc.

2.5 Mass Customisation Strategies.

Manufacturing can be described as a series of operations directly involved in creating a product Karlsson (2002). There are however, many different definitions of manufacturing. One very important factor required to succeed in production, is an overall strategy that considers future trends, market demands and technological development Slack (1998). A good example of the above considerations being put into practice would be the Toyota production system, which had clear goals and ways of which to achieve them. Assembly initiated production (AIP) is designed to be such a strategy.

Important factors when developing an AIP are:

a) Shifting production volumes, must ramp up and down quickly, in response to the order volumes. (Large capacity fluctuations)
b) Shorter product life spans
c) High, and continuously increasing number of product variants.
d) JIT delivery

AIP strategy takes into account the above factors, and in order to work it needs to involve all areas involved in the production. These include:

- The ability to reconfigure manufacturing systems to adapt to different products.
- Product designs that assist the production process, while at the same time satisfying customer requirements

- IT systems that can support the production process, however these will need to be reconfigured like the manufacturing system.
- A supply chain that fully supports the manufacturing process
- Flexible and competent personnel who have the ability to identify situations and deal with them in an appropriate way.
- Human – machine interface training throughout the workforce and consideration of the environmental issues Lee (1997).

The above are linked back to mass customisation. Mass customisation emerged as manufacturers, enabled by their proficient lean production systems, explored ways to better meet the needs of the customers Alford *et al* (2000). A typical diagram of an AIP structure was devised by Karlsson (2002) is shown in figure 2.5. This shows the hardware flow and information flow through the production process.

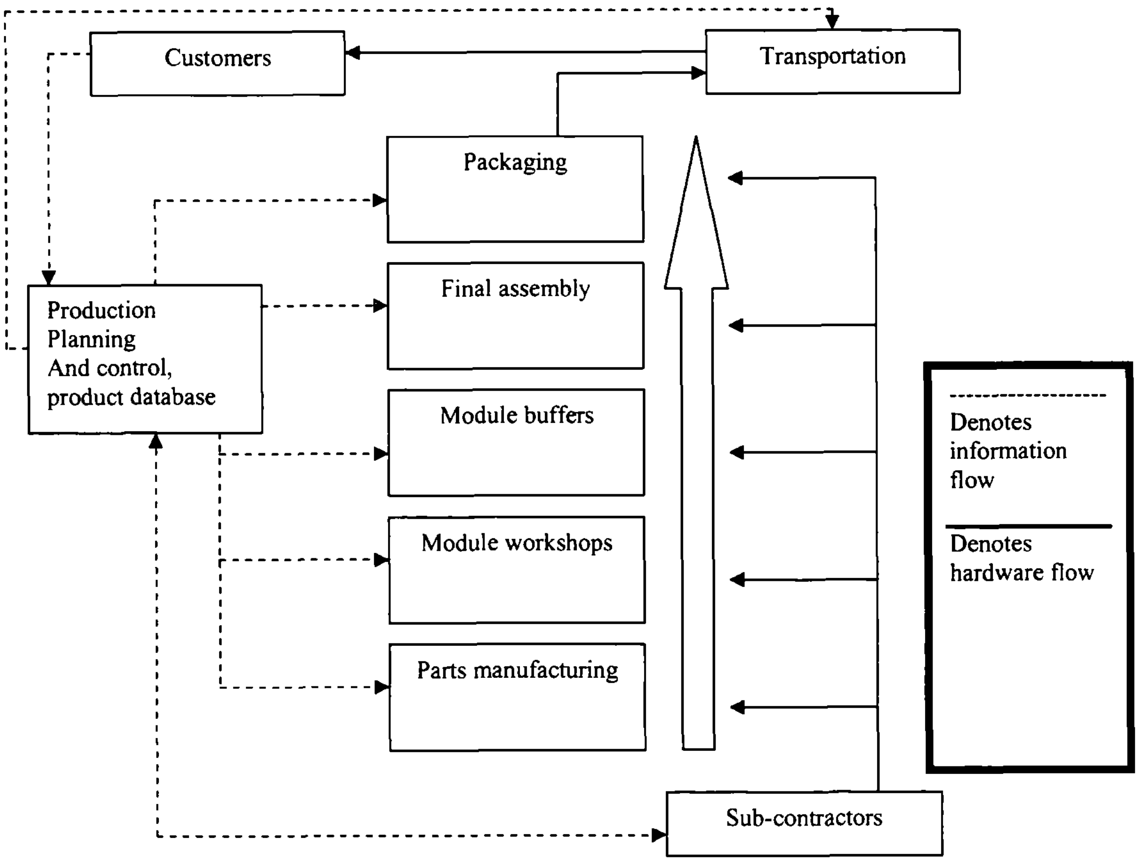


Figure 2.5 The AIP Model

The Assembly Initiated Production model.

1) The customer order enters the computer system and is immediately available to the whole manufacturing chain
2) The final assembly will be able to see orders in the system at an earlier stage, which will lead to responsive production
3) Standard components should be stored closely to the line. When an order is initiated, components will be taken from the storage and assembled into the necessary products
4) The finished goods are then packed and shipped to the customer
5) The demand is placed on parts, ordering of components from suppliers etc.

The AIP model is not unique and is used in many corporations throughout the world. What separates those companies that do well to those who do not, is the ability to efficiently manage each area Otto (1999).

A comparison can be drawn between those compaines performing mass customisation to those demonstrating a mass production strategy.

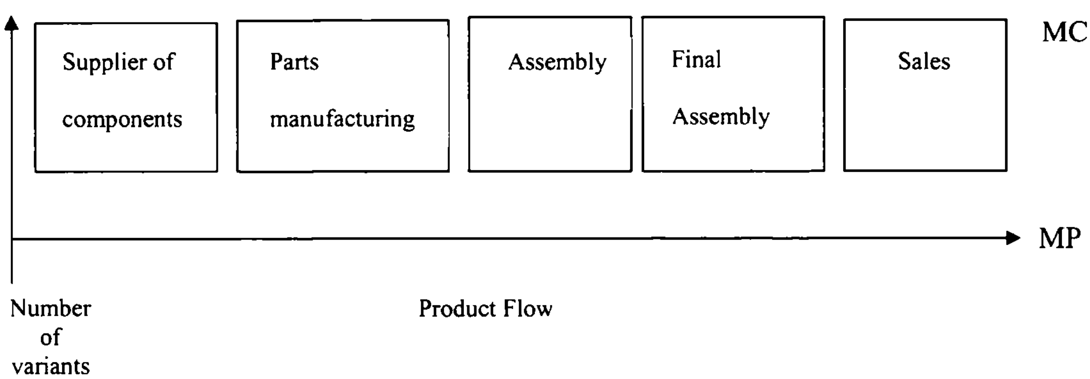


Figure 2.6 Effective AIP Flow

Figure 2.6 process flow diagram as derived by Karlsson (2001) shows how the amount of variants of components can be processed in an AIP production flow. In a mass customised environment you would expect to see an increased number of variants running along the product flow. A mass production operation would run with a low level.

Whenever implementing AIP, it is important to build in flexibility to the production line Onori *et al* (2000). It may be possble to use existing machinery, however it has been observed that the use of manual operations can bring a large proportion of flexibility to assembly operations. In order to increase flexibility in automatic assembly, an AIP project was formed with the Hyper Flexible Automatic Assembly (HFAA) project Onori *et al* (2000).

The benefits that were to be gained from a standardized solution would be as follows:

- Shorter installation times
- Lower investment costs and related risk factors
- Simple re-configurations of original layout
- Second hand market equipment.
- To do this would include the standardization of mechanical, pneumatic and electronic software. This will allow transportation of mediums without adjustments.

AIP Summary.

The AIP strategy is very well suited to mass customisation, as it highlights the need to build flexibility into the process, whether it is automated or manual. The central point in the AIP methodology is the process. It can be measured by the:

- Input, the material and resources
- Output – the product
- The infulence that the process has on its environment

This can otherwise be referred to as the Functional process area (FPA) Karlsson (2001). The FPA has various influences on its environment. These can be defined as:

Flexibility – the ability to produce new products, to manufacture different product variants and to change capacity to meet changes in demand.

Speed – these include lead times, the requirement to adapt to production in a short time.

Robustness – the reliability of the systems when considering down time, breakdown and quality output.

Resources needed – the amount of resources required to to manufacture the product through the FPA. This may be measured in money, hours etc.

The above areas can be measurable factors that can be used within factory operations and can be applied at different levels of manufacturing.

2.6 Manufacturing Strategies for Mass Customisation

There are many deinitions given by many authors on what a manufacturing strategy is. It can be summarised as ' a sequence of decisions that over time, enables a business unit to achieve a desired manufacturing structure, infrastructure and set of specific capabilities' Hayes *et al* (1985). It can also be defined as ' a critical part of a firms corporate and business strategies, comprising a set of well coordinated objectives and action programs aimed at securing a long term sustainable advantage over competitors' Fine *et al* (1985).

When looking at manufacturing strategies, and in particuar those for mass customisation, it is necessary to understand exactly what should be included as illustrated by Dangayach *et al* (2001) in figure 2.7. It is possible to break down the strategy to examine its content and process. The content can be generic but the process will in most cases be specific.

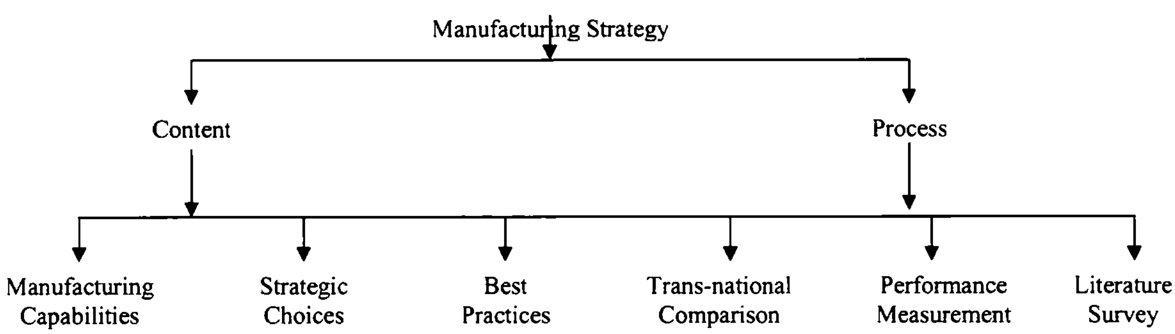


Figure 2.7 An Example of a Manufacturing Strategy

The contents of a manufacturing strategy should incorporate the strategic choices in the process and the required infrastructure. It is important to recognize that companies manufacturing role was more than to simply produce and ship products. The manufacturing objectives should in fact cover the following:

- Cost – production and distribution of product at a low cost
- Quality – manufacture of products with high quality or performance standards
- Delivery – meet delivery schedules

- Flexibility – react to changes in product, changes in product mix, modifications to design, fluctuations in materials, and changes in sequence Skinner (1969).

Manufacturing capabilities can be achieved by considering all of the above objectives through every step of the manufacturing process.

A good example of strategic choices would be the Plant and equipment, production planning and control, labour and staffing, product design and engineering and organisation and management Hayes (1985).

2.6.1 Best practice

These have become more popular in recent times with a more focused approach to optimised production technology, flexible manufacturing systems, group technology, TQM, JIT lean production and concurrent engineering. All of these can lead to the concept of WCM (world-class manufacturing) Schonberger (1986).

2.6.2 Trans-national Comparison

Globalisation has led to increased competition throughout manufacturing. It is no longer concentrated in one country, but spread over distant locations across the world. For this reason it will be important to compare strategies and practices of countries such as the USA, Europe and the Far East (Japan and Korea). It may be possible to identify the specific factors that may give certain countries the competitive edge. This can also link back to the best practice and optimised production technology.

2.6.3 The process approach

The process approach focuses on the design, development and implementation of the manufacturing strategy. Platts (1993) suggested that an audit based approach to develop Manufacturing Strategy. The three stages are; creating the process; testing and refining in a small number of companies; and investigating wider applicability by means of a survey. Gilgeous (1993) discussed manufacturing strengths such as technology, capacity etc. and weakness like lack of fit between manufacturing and marketing objectives of the industries.

2.6.4 Performance measurement

As previously mentioned, Cost, Quality, Flexibility, Delivery and innovation are well-established competitive performance priorities. To measure the performance of MS, it is necessary to develop a comprehensive system that matches the manufacturing mission of an organisation.

2.7 Green Manufacturing.

2.7.1 General

In an increasingly environmentally conscious world, it is necessary for companies to be eco efficient. Skinner (1969) explains that those companies that can manage their resources more efficiently are likely to achieve a more competitive advantage. Eco efficiency means to run manufacturing operations more innovatively, responsibly and ultimately on a more competitive basis Dangayach (2001).

With manufacturing companies increasingly focusing on procedures such as TQM (total quality management), the issues of productivity have undergone a strategic shift. This means that manufacturing strategies must consider environmental concerns and aim to minimize the waste in an eco-efficient manner. Klassen (2000) discovered that increased investment in quality management offered an important route to expand the implementation of pollution prevention, and emphasised green productivity as a new paradigm to evolve the WCM (world class manufacturing) strategy.

Green WCM would ideally be value added in that there would be controls introduced through waste reduction management, waste avoidance and waste prevention. The outcomes of which would be zero pollution, zero defects, zero downtime and zero inventories. When considering eco efficiency for MS and mass customisation, it may be necessary to consider the following research issues, as detailed by Dangayach (2001).

1. How "green" is the manufacturing? A framework may be required to measure the impact of various environmentally friendly activities pursued by the manufacturing function.
2. Evaluation of some "green" indicators in the performance measurement system, which facilitate such a system.

3. The role of manufacturing strategy in making an organization into a responsible corporate citizen
4. The impact of various accreditations such as ISO 14001

2.7.2 Green productivity – A Case Study.

Historically, industrial organisations have used productivity as a dominant measure. Concerns around productivity arise when the rate of growth in productivity determines the economic stability of the country in which the company resides. There are increasing pressures on organisations and nations in attempting to maintain a steady increase in productivity – increasing competition from both domestic and international players, scarcity of raw materials, cost of energy and manpower etc. Mohanty.R. *et al* (1999). There were also concerns on the negative effects on industry – the ecological damage caused by industrial processes and using up the worlds natural resources. This can lead to companies taking a fresh look at productivity and develop new strategies to counteract these issues. One way in which these concerns can be addressed is through the implementation of green manufacturing strategies. This is particularly prevalent in the developing world, where organisations are attempting to bridge the gap with the developed world. This can put extreme pressures on the physical environment Hurt (1997).

Green productivity can be described as the search for clean technologies that reconcile the need for higher output with additional focus being to protect the environment. It has now been recognised as a global issue and is now being adopted as an organisational philosophy and a set of strategies to manage production innovatively but responsibly, and ultimately, on a more sustainable basis Hitomi (1997).

The reduction in the use of energy and raw materials will obviously be good for the environment, but can also be financially beneficial to a company because they can reduce operational costs. Mohatny *et al* (1998) was able to establish a very direct relationship between resource productivity and resource waste. Any non-value added activity carried out in the process could be classified as waste.

The company ABC is a leading manufacturing company in India with an annual turnover of 50,000 million rupees. The company has many areas of activity including; mining, geology, process engineering and the production of steel and cement. The company had a strategy to investigate the opportunity for improving profit. The "greening" of production was identified as a means of both improving profit while improving the corporate image. Traditionally, in manufacturing, waste is assumed to be a simple function for the operational process. However, the reality is more complex and there may be both a structural and operational dimensions.

Structural dimensions are the amount of structural waste influenced by the scale, scope, complexity, layout and configuration of the manufacturing process and additionally by the ancillary attributes such as control mechanisms.

Operational dimensions can include incompetent and poorly trained workers, inadequate quality systems, poor operational planning and scheduling, poor materials planning, badly maintained equipment, inadequate tools and poor working conditions. In addressing the control of waste, it is necessary to look at both structural and operational dimensions.

In this particular case, individual departments were responsible for their own quality and waste targets. The basic focus was to achieve involvement of all stakeholders in identifying the waste that is generated and analyse the root cause and ways of eliminating or minimising it. Facilitators were identified to lead focus groups that concentrated on the primary and major causes of waste to ensure that simple approaches to improvement were identified. They did this by constantly reminding the groups to include the widest range of system inputs and consider the various stages of the manufacturing process where the waste may arise. Once the sources were identified, they were categorised according to their perceived contribution to actual waste levels. These are then addressed in order to create a greener process.

The identification of sources of waste benefits from an exclusive approach to which all stakeholders and participants contribute. For this to be effective, training and education would almost certainly be necessary. Avoidance of waste is equivalent to resources provided. Implementation of waste minimisation and revise strategies can provide a competitive advantage.

The green / environmental factors should certainly be considered at every stage of new product introduction. This can start from the impacts of design at the concept stage, through to the environmental impacts once the product is in the after sales market. In a company that operates a mass customised strategy, this may be difficult to achieve.

However it may be possible for teams to be assigned projects and to focus on perceived areas of waste, similar to that in the above case study.

2.8 Simultaneous Engineering for Mass Customisation.

Simultaneous Engineering (SE) is increasingly becoming a major parting the modern manufacturing design and development process. SE is the integration of research and development, product design, process planning, manufacturing, assembly and marketing into one common activity Delvar *et al* (1992). At the core of the SE process is joint design and production team whose role is to comment and redesign from each of the domain experts. It is crucial that communication and information flow among the experts, as this is crucial to the success of SE.

A good example of where SE can be seen is in the automotive field, where there are several fields of expertise required. These can include; mechanical engineering, electronics, materials, robotics and computer software. This complex process of innovation requires systems organisation between different technologies and types of expertise. In most cases new technology, production methods and market requirements can have a large impact on an organisation. This in turn can have an impact on the suppliers and manufacturers Imai *et a*l (1991).

The best way to link SE to mass customisation is to look at a typical manufacturing paradigm, where the design is passed through various stages of production. The product conceptions come from the market experts requirements and are submitted to the designers. They will in turn determine product specifications and send the product design to the manufacturing function. They will specify the production system and process to enable the manufacture of the design. This is shown in figure 2.8.

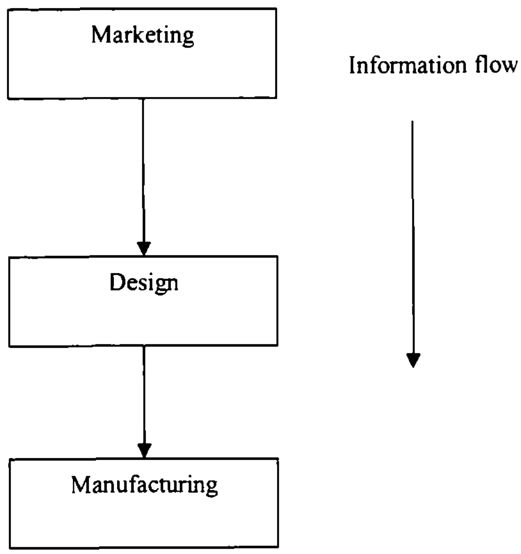


Figure 2.8 Example of a Manufacturing Paradigm

The manufacturing department will receive information from production system experts on the purchase of manufacturing equipment and the expected ROI (return on investment). When looking at mass customisation strategies, it will be necessary to consider all of the above functions in order to meet specific customer requirements.

The initial input of the product cycle therefore, is a set of marketing needs including market value and the output is the production cost.

If the production cost is too high then the whole SE process must be repeated by modifying the design to one of the stages illustrated above. Bessant (1991) explains that this iterative and sequential process requires very little interface at the divisional boundaries of the company. The domain experts in each technological field are usually located in physically separate departments with minimal communication across organisational boundaries. In order to utilize SE, there is a requirement for change in the internal organisation of the company. The amount of change required will depend on the complexity of the product, organisational capability, resource capability and the commitment of the company to the SE concept.

2.8.1 Internal organisation for Simultaneous Engineering

One of the key areas in SE is the information flow between different functional areas. Information systems have been developed in the form of database and electronic communication media Maruyama *et al* (1991). This coincides with regular visits to different functional departments by a nominee who acts as a central link (usually an engineer). It is important that this person performs information processing function and a liaison for communication of information between the expert domains. In order to be fully effective this person should be knowledgeable on different aspects of the production process and the way in which they must be integrated to achieve SE.

In order to further develop the function liaison theory, it may be necessary to introduce cross-functional teams. The team usually consists of a designer and a manufacturing engineer who work together throughout the whole process. Delvar (1992) stipulates that the frequent interaction involved permits cross-pollination of ideas and techniques and allows for mutual education of domain experts. This can in turn contribute to the enhancement of capabilities of all team members and can lead to increased innovation

Each member within the team is still part of their functional department and can therefore have two hierarchies to whom they must answer. There is potential for rivalry whereby the 'loyalty' of team members is first to their department and only second to their team Delvar (1992). It is therefore important for employees to focus on a successful outcome of the project rather than cross-functional politics. This message should be also addressed to the functional managers, as it will be important for them to be supportive and understanding.

A more integrative approach involves a larger structural change within the organisation of the company. This would involve creating a department responsible for both product and process. This would help generate SE and product / process education throughout the department. It is extremely important that the designers attain a coherent understanding of the production process, as this will help DFA (design for assembly) and possibly remove cost from the initial concept. Other advantages in having a single department allows constant contact with all team members which can lead to uninterrupted information flows between production modules, and more importantly team members will be subject to uniform managerial hierarchy.

The implementation of a single department responsible for both product and process in not an easy route to take as it requires a change in the authority and power which many existing functional managers may be reluctant to change. Because of better information flows, greater initiative by technical personnel and reduced need for supervision, there is an opportunity that the number of middle management positions could be reduced.

Many corporations throughout the world have embraced the SE concept. BMW automotive manufacturers are a good example where significant change has taken place. They have the largest single research-engineering centre in the European industry in pursuit of SE principles. The 'Fiz' centre located in Munich is a futuristic maze of towers and multiple-connecting walkways that house nearly 6,000 engineers, none of whom has to walk more than 150 meters to walk to a colleague. The internal layout allows first-concept designers to discuss easily with a production line engineer the manufacturing practicalities of even an outline design idea. According to its research manager, this somewhat radical implementation has been able to cut BMWs development cycle by two years. The design of the building is based on the concept that, if physical distances between two design engineers are greater than 150 meters, the interchange of ideas and information is discouraged. Chrysler has undertaken a similar concept, whereby the manufacturing facility has been designed to facilitate information flows between different stages of production. Team members included design engineers, production engineers, marketing managers and even financial officers. The result of the viper sports mobile has taken only two years to develop.

SE is most extensively practiced in Japan where it is referred to as Doki-ka. Companies who use this practice include Matsushita, Jujitsu, Sony and other manufacturers Imai (1991). The Doki ka's strategy is similar to SE but its scope includes the marketing function. The idea of a new product flows from the marketing department to the design and process development department (DPD). The information that comes from the marketing department includes performance, quality and functional capability. The DPD starts to develop the new product or the refinement of an existing one, which conforms to the marketing department's requirements. Within the DPD, multi-functional teams are used to facilitate Doki-ka.

2.8.2 Suppliers Role in Simultaneous Engineering

Manufacturing has traditionally required a simple supplier arrangement. Supplier products were usually standardized and required little customisation. The rate of change was slow and the overarching manufacturing consideration was low cost Shapiro (1985).

Suppliers were able to achieve reasonable but not perfect quality standards, and quality control was usually though batch inspection. Automobile manufacturers worked with a large vendor base and the relationship with each vendor was arms length, formal and often short term. In this system, a designer in the OEM Company would draw a design with the required specifications and send it to the supplier. This information included design specifications with the physical attributes and performance parameters. There was little contact between the designers of the OEM and the production engineers of the supplier. This meant that the process capability of the supplier was unknown to the designer. It was left in the hands of the designer to decide upon issues such as the manufacturability and ease of assembly. In turn the suppliers manufacturing experts relied on their own experience to determine what changes could be made to make the item producible. The supplier would then modify the process to produce the components. However, because the process engineers received detailed documentation, changes in the existing production process would seriously increase the production costs and create problems at the OEM. To summarise, the knowledge of the process capability of each Vendor was not designed into the product. These types of problem can be put down to the inadequate information flows between different production systems.

Because of new technologies and market competition, it is important for manufacturers to respond to the challenges. The need for customised, higher performance and quality parts has dramatically increased the strategic importance of suppliers in the overall success of the company. The emergence of such technologies as mechatronics (a combination of mechanical devices and electronic parts) and optoelectronics (a combination of optics and electronics) has led to cross-industry information exchange.

Given the new technological requirements, the effective deployment of SE requires a change in the relationship between the companies and their vendors. The OEM's reliance on the design capability of the vendor is much greater than under the standardized system. The coordination and transmission of technical information between

OEMs and their suppliers can best be achieved through the creation of cross-functional teams. This will require the input of domain experts from OEMs and their supplier companies. Joint design and production effort of OEMs and their suppliers can lead the end products that incorporate quality, manufacturability and ease of assembly considerations and reduce the need for redesign of the product or process.

Before achieving a closer relationship, OEMs and their suppliers must overcome several business barriers in order to achieve closer co-operation. Firstly, some suppliers are unwilling to divulge their production costs. If there is a significant profit margin, the OEM may demand minimum profit margin for suppliers.

There may also be a requirement when a product is semi standardised and there is need for customisation, specific asset investment might have to be undertaken by suppliers Williamson (1985).

2.9 Product Design Development

Many manufacturing organisations have realised that in order to compete within its specified market, it is necessary to make use of the advances in technology with cost to be kept to a minimum. Cost is related to the design of the product; therefore it is necessary to look in detail at DFA (design for assembly) Onwubiko (1992).

Design for manufacture and assembly is a product design review process involving step by step assessment of manufacturability issues. The design for assembly module helps with the simplification of the design, while the design for manufacture module assists the selection of materials and processes and provides piece part and tooling cost estimate feedback Boothroyd (1989). The flowchart figure 2.9 summarises the procedure for the creation of a product.

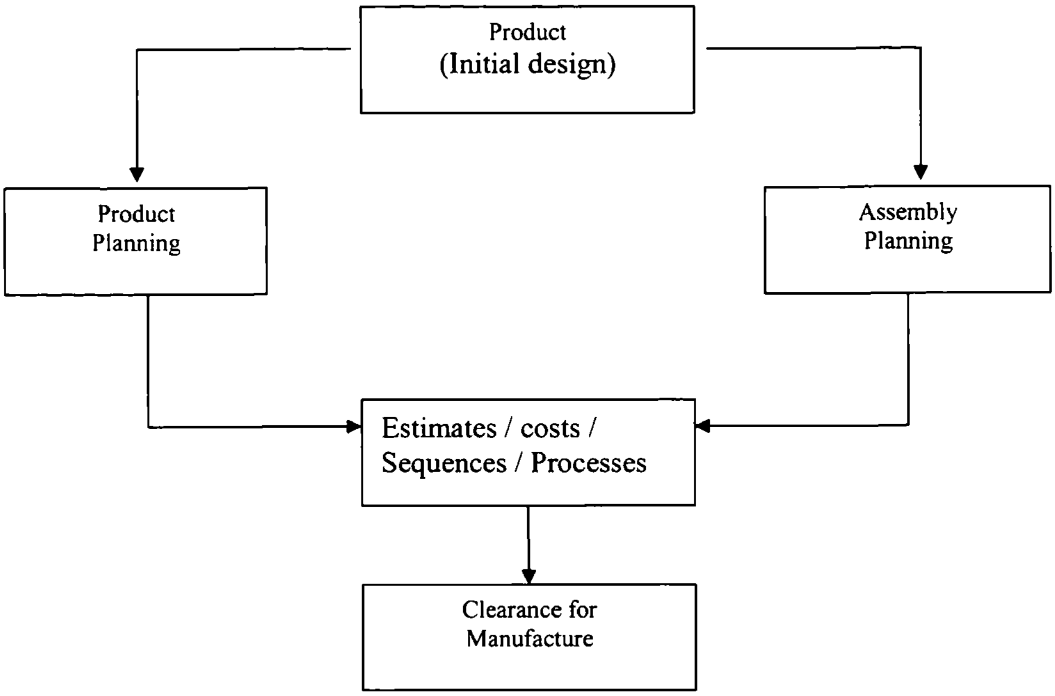


Figure 2.9 Flow of project creation

The selection of a good sequence of assembly operations is a crucial factor in maximizing the production profitability and has a great impact on the assembly line balancing, machine utilisation and feasibility of sub assembly operations Ben Ariah (1994). Bullinger *et al* (1991) gives a good definition of DFA and can be considered as the synthesis mechanism that converts the specifications of product design, manufacture, quality control and other downstream activities into manufacturing reality. A seven-step design for manufacture process has been developed in order to reduce manufacturing costs without compromising the product quality. The procedure consists of a number of different activities that must be carried out sequentially. These are as follows:

2.10 Design For Manufacture

Analyse the manufacturability of present products and compare with similar products on the market.

Objectives

Setting objectives for the manufacturability of the future DFM product.

Main functions

Clarification of the various functions of the product and their interaction

Evaluation parameters and design ideas

Confirmation of evaluation parameters and design ideas for each main function, and for the four focus areas: corporate, family, structure and component level.

Generation of alternative designs by determining the product characteristics in a top down manner. These must coincide with the four DFM activity levels:

- Corporate level – interaction with other types of company products
- Family level – the relationship between different variants in the same product family
- Structural level – the relationship between the different components
- Component level – the design and specification of each individual component

Verification and selection.

Measuring the manufacturability of the proposed conceptual designs and comparing them with the DFM objectives. It will be necessary to select the overall best concept design

Detailed design.

Completing the detailed product design and fulfilling the concept criteria.

When undertaking a seven step DFM process, it is important to measure the manufacturing performance and product design in terms of characteristics. These are described by Olesen (1992) as the "universal virtue" areas:

Product costs – the direct cost of labour and materials. The overhead costs (indirect costs) which include shop floor management, space cost, production control, quality cost, purchase etc

Quality – the ability of the product to comply with the desired functionality. This should include a low level of quality control, rework and scrap cost.

Flexibility – The versatility of the adaptability of the manufacturing (related to the product design.

Risk – the manufacturing risk built into the product design

Lead time – the ability of the product to allow a shorter assembly time and a reduced time to market.

Efficiency – how efficiently can personnel be utilized and how efficiently can our resources be utilized?

Environment – what will be the environmental consequences of the product design during the manufacturing process?

Analysis of the seven-step procedure used in mass customised and mass production environments can reduce the manufacturing cost by 30 per cent Fabricius (1994). This reduction can be achieved due to the following:

- The increased focus of the design team on clear and common objectives
- Taking ownership of the problems by addressing all seven universal virtue areas
- The prevention of premature focus on component problems by considering the corporate level, the family level and the structural level of the product first.

2.11 Production facilities and anticipated product mix.

It is essential that product designers consider the process capability to determine whether or not a product can be manufactured or assembled. Where there is a mass customised environment, it will be important for the product designer to be aware of the impact on process capacity of the total product mix at the time of introduction of new product. It may be that a demand to increase the time to market may contribute to the oversight of existing assembly related issues. In order to address this issue, it will be necessary for the product designer to implement the DFEE (design to fit and existing environment) methodology. DFEE comes in a range of tools that can help in designing new products to fit anticipated capability and capacity and should concurrently encourage process changes that will lead to process flexibility. This is an extremely important factor to consider when implementing products into a mass customized environment. Process flexibility helps to minimize the effects of dynamic environments, while extending the useful life of capital equipment to a greater range of products Taylor *et al* (1994). System flexibility can enhance the ability of a company to meet operational goals rapidly both in terms of rapid response and customer delivery requirements.

The time to market for new products is a good benchmark to measure the ability of management to meet targets and there may be significant pressures to perform relative to this benchmark. New products must be integrated with minimal / no disruption to the production process. The DFEE concept tries to minimize disruption by encouraging the design of products to take advantage of slack capacity and the revision for the timing of release of the product to manufacture.

2.12 Manufacturing Capacity.

One of the areas that DFEE considers is manufacturing capacity. This can be measured in terms of labour hours available and the ability to produce a certain aggregate mix. There are two ways in which this information can be collated, the first through system simulation, the second through theoretical calculations using static models. The theoretical static utilization of a process can be described in the formulation presented by Behuniak (1987).

$$U_{jk} = \left[\frac{N_{jk}}{A_{jk}}\right]$$

A_{jk} = time available at process j in period k (hours)

N_{jk} = time required at process j in period k (hours)

U_{jk} = utilization of process j in period k (hours)

An U_{jk} value less than 1.0 means that the process is capable of meeting the production requirements in a particular period. A value greater than 1.0 indicates that either additional processing capacity must be added or the process will be incapable of meeting demand in the period.

General DFEE techniques can be implemented using simple rules. The following general steps can be used as a guideline for DFEE implementation:

1.0 Identify the anticipated product mix and process configuration at the scheduled release time

2.0 Find the throughput limiting process

2.1 Determine if it is possible to redesign the product to offload work to another process

2.2 Establish trade off rules

2.3 Determine the direction of the "most probable" maximum improvement and step size

2.4 Make suggested change; go to step 2.

3.0 Alternatively add and subtract one period from the target release period

3.1 Determine if the cost of changing the release date (charges due to expediting or lateness) is less than the increased profit from operations. If less, continue; otherwise go to step 4

3.2 Make the change; go to step 3

4.0 Determine if the cost of adding one unit of "bottleneck" capacity is less than the profit from increased sales. If less, continue: otherwise go to step 2

4.1 Add one unit to the bottleneck capacity; go to step 2

5.0 Complete the design process. Strive for continuous improvement.

These steps are designed to be applicable to a large range of manufacturing companies and could be used to meet the constraints of a design team. The consideration of offloading work to a number of other facilities or suppliers could easily be included. Concurrent design of a family of products is also a realistic opportunity.

When deciding upon a manufacturing strategy, it is important to develop charts to demonstrate an ongoing approach to strategy development. A key requirement for an ongoing strategy process is an easily updatable representation of a company's strategy Charts can enable managers to reflect on the patterns of planned and unplanned events and their strategy on an ongoing basis. The outline of a manufacturing strategy process is accurately illustrated by Mills *et al* (1998).

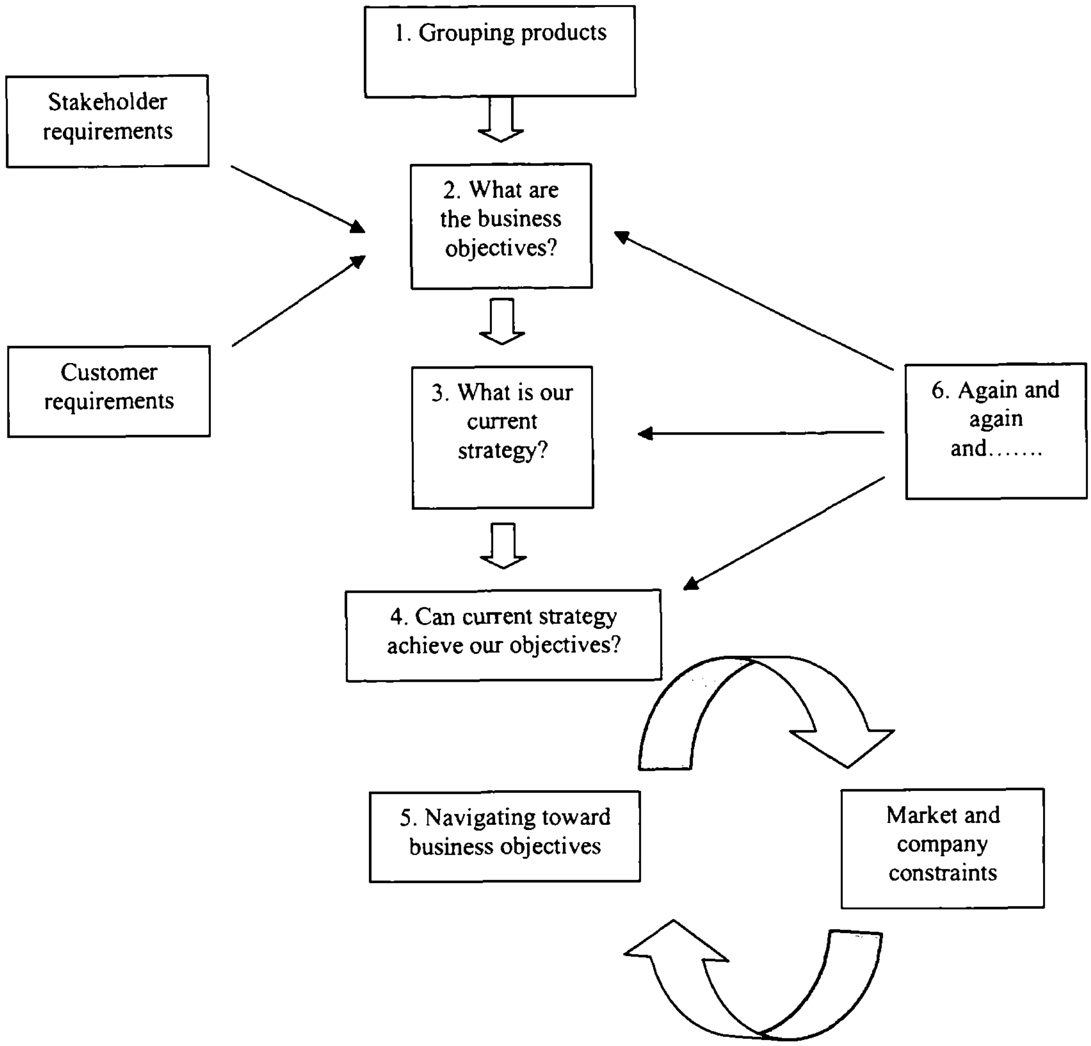


Figure 2.10 Strategy Development Process Flow

- The grouping of products will enable the valuable collation of information for example; sale value and trends, contribution and product life cycle information which will help to decide which product group should be dealt with first. Each product group will be dealt with separately as it is unlikely that the same strategies will be the same.
- The second stage identifies the product group market requirements and also includes the ambitions of other stakeholders for example managers, owners, employees and suppliers.

- The third stage identifies the current manufacturing strategy. A suggested method for achieving this can be a discussion that focuses on the strengths and weaknesses within the current strategy. These can be represented as a matrix of keywords or phrases.
- Stage four analyses current strategies against the requirements established at stage two with a straight forward gap analysis.
- Stage five allows new ideas to be assessed against the requirements in stage two. It also allows ideas to be evaluated against strategies highlighted in stage three
- Stage six concentrates on implementation and establishing an ongoing strategy process within the business

This kind of strategy process chart will be extremely useful in driving a top-level plan for mass customisation. It will enable the constant re-evaluation of the products by product type, which is important when competing in a customised environment.

2.13 New Product Design Integration into Existing Production

Reduced product life cycle is now inherent in manufacturing and companies are looking more and more to reduced time to market. Engineering design plays in an important role in the successful manufacture of products. It is of key importance that products are designed to support efficient production, especially in a customised environment. The most influential factors that can help achieve this are DFA (design for assembly) and DFM (design for manufacture). Gatenby (1998) generalises the entire strategy of related design strategies as DFX where X represents a broad variety of considerations.

It is almost certain that product designers are not aware of the impact on process capacity of the total anticipated product mix at the time of introduction of a new product. This is something that will be recommended as part of the procedure for NPI (new product introduction) in a mass customised environment.

2.14 Agile Manufacturing.

An agile company can be described as one that embraces change and adapts to it rapidly and easily. Agility is the ability to be able to reconfigure operations, processes and business relationships efficiently while at the same time operating in an environment of continuous change Womack *et al* (1991). Manufacturing techniques must be well thought long term strategic plans. Agile manufacturing is a top-down corporate wide effort that supports the time-to-market aspect of competitiveness. Cooperation between companies is important to support the requirement for quick decision-making. It is also important that companies work together to achieve the overall goal of improving manufacturing, and employees need to be willing to expand their horizons in order to achieve greater creativity and flexibility in the way they perform their jobs.

Agile manufacturing can be described as a method of manufacturing which will provide a competitive edge for companies. Agile organisations produce a high quality defect free product with short lead times. The product is able to be upgraded and reconfigured, rather than be replaced. This is of particular use when operating in a mass customised environment. An agile manufacturing organisation integrates design, engineering and manufacturing with marketing and sales in such a way that the products are customised to the exact needs of the customer. Its goal is to produce products that completely satisfy customer needs and wants Nagel *et al* (1991).

A good example of where agile manufacturing has been implemented successfully is General Motors that made the transitional change in 1993. They reduced lead times by 38 per-cent, its inventories by 48 per-cent and its floor space by 27 per-cent Kasarda *et al* (1998).

Those companies whom embrace agile manufacturing are flexible and quick to respond to fast moving market conditions. In order to increase the effectiveness of multi functional product-development teams, companies may set targets for the teams to achieve. These may include quality levels and throughput etc. The management within these teams is flexible and prone to constant change and they will be responsible for ensuring that information flow through the organization is smooth and uninterrupted through the functional areas. The managers should also look beyond the internal cross-functional teams the aggressively pursue market opportunity. They should also be able to identify any strengths and weaknesses within the team and be able to make the necessary changes.

When comparing different manufacturing paradigms it is possible to see the advantage that agile manufacturing can bring to an organization from a socio-economic point of view. More and more companies are considering the work / life balance as part of their overall operating strategy. This can be effectively illustrated in the manufacturing paradigm table by Amir (2001).

Manufacturing Strategy	Standard of living	Free time of employees	Creativity of employees
Craft production	Increased	Increased	Increased
Mass production	Increased	Decreased	Decreased
Lean production	Increased	Decreased	Increased
Agile production	Increased	Increased	Increased

Figure 2.11 Manufacturing Paradigm Table

2.15 Fractal Manufacturing Partnerships.

It is necessary for companies to respond rapidly and with flexibility to the needs of a customer. By involving suppliers from the initial product development through to final assembly, can reduce product development time, reduce manufacturing expense and improve product quality. Companies tend to focus in achieving excellence in their core business, with non-core business being handed over to suppliers who are able to demonstrate their capability in handling the task. Shared strategy requires a high level of commitment and trust between both parties.

When considering JIT for FMP it will be important to consider the shipment of parts from the supplier to the OEM assembly plant. This will require a large amount of space within the assembly plant. This type of delivery is consistent with the OEM supplying the product design and the supplier delivering the material as required.
JIT II encourages closer interaction between the OEM and supplier. In order to achieve this, the supplier has a representative in the OEMs plant that has access to all information that is required regarding ordering and inventorying supplier components Noori *et al* (2000). This is designed to improve quality and enhance communication between OEMs and suppliers. JIT II also enables both OEMs and suppliers to respond to production

changes with speed. Modular sequencing encourages even closer interaction between the OEM and suppliers.

The supplier maintains real time information on scheduling activities in the plant. The resultant factor is improved communication and accuracy and ultimately less inventory on the assembly line, as sequenced modules require storage and assembly line space in the plant Dinsdale (1996).

FMP (fractal manufacturing partnerships) can bring many advantages to a manufacturing organisation. It can lead to a leaner production that can in turn lead to a higher degree of agility. Other advantages can include:

- Improved communication between OEMs and suppliers leading to transparent information change.
- Faster engineering changes and problem resolution
- Reduced assembly time and improved productivity
- Reduced inventory and improved quality
- Reduced product development cycles and faster product launch
- Improved responsiveness as a direct result of improved communication and faster product development
- Improved design for manufacture, where the supplier is directly responsible for assembly.
- Shared benefits between OEM and the suppliers due to commonality of goals and shared ownership Noori (2000).

2.16 Lean Manufacturing.

It is much publicised that lean manufacturing is the superior way of producing manufactured goods. The Japanese automotive companies are a good example of where a framework is developed as a means for designing and assembling products in less time with fewer people and lower inventories than its competitors. The essential elements of lean production are illustrated by Katayama *et al* (1996) and shown in figure 2.12.

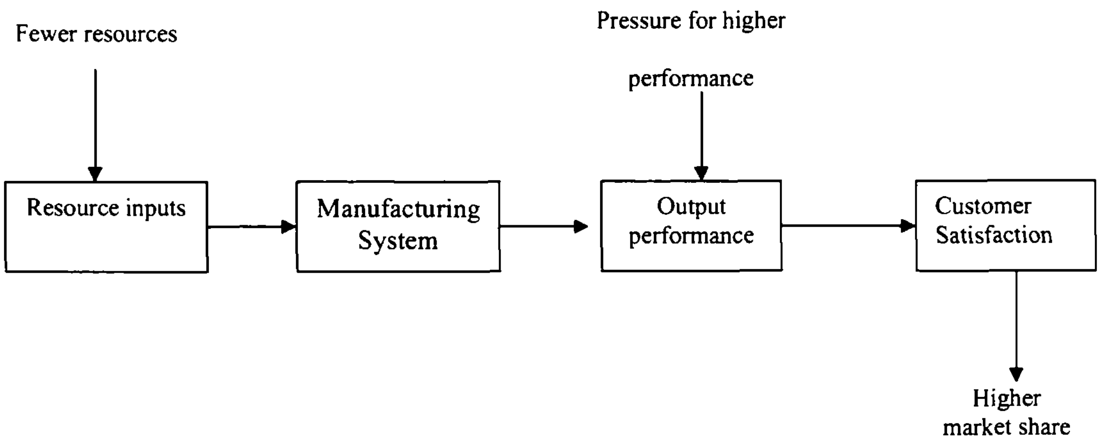


Figure 2.12 Elements of Lean Production

When considering lean manufacturing the main objectives for companies will be to increase market share by reducing costs and prices as well as offering a greater variety of products with more features. The main competitive pressure is to expand market share and the principal means of achieving which has been through price competition. This in turn has reduced profits, which necessitates cost reductions and increased revenues. It is also possible to achieve cost reductions through continuous improvement activities.

The lean cycle is illustrated in figure 2.13 and can be used as a framework for which companies can model themselves.

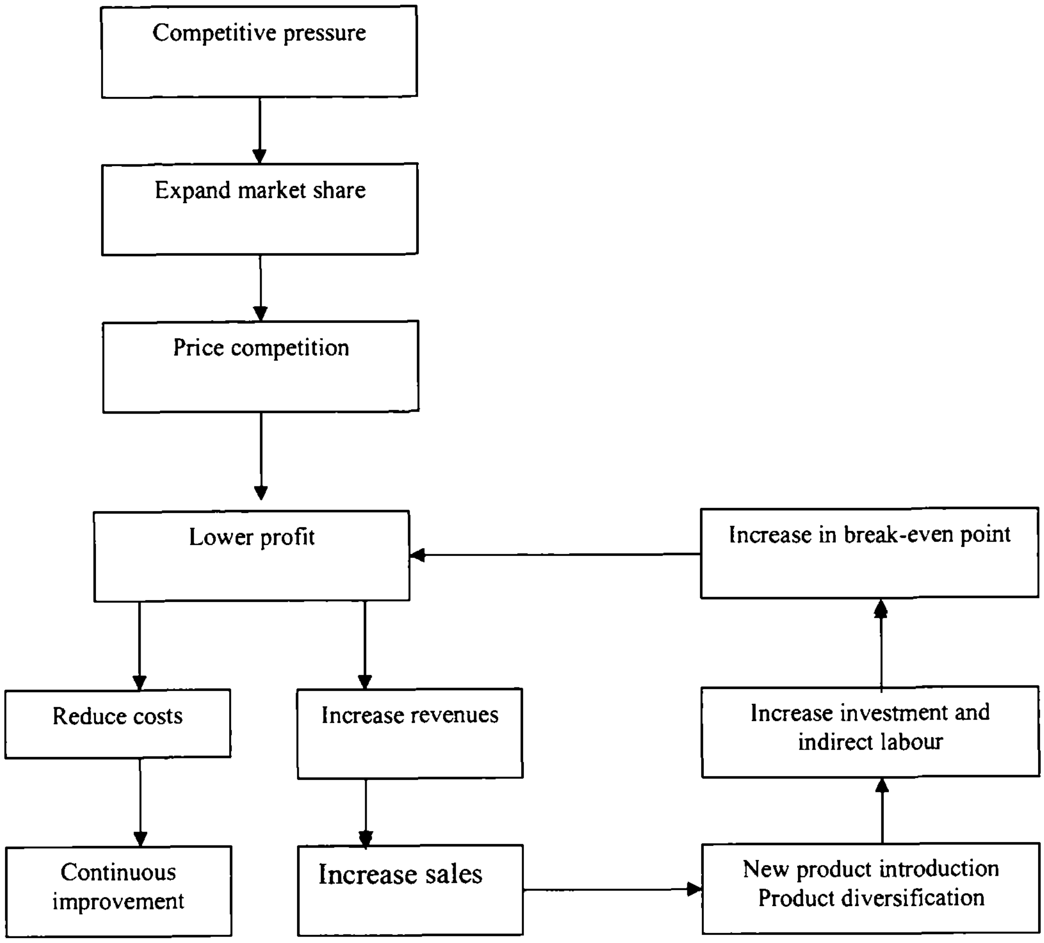


Figure 2.13 Lean Cycle Framework

Figure 2.13 shows the kind of impact competitive pressures can have throughout a company's overall operating strategy. When analyzing the lean manufacturing chart, it will be important to consider whether elements of this can be integrated into a mass customisation strategy.

2.6.1 Lean manufacturing - environmental influences.

Since the introduction of lean manufacturing, there have been many concerns highlighted in Japanese manufacturing and the application of lean production methodologies and technologies. Some of these concerns relate to the external environment of companies, while the others relate to the internal production environment .One area documented in the Japanese press was the increase in traffic brought about by smaller, more frequent deliveries of equipment and materials to factories. The impact of this is increased urban congestion and the creation of long queues of delivery vehicles on the countries main auto routes. In Japan, places such as Tokyo, Osaka, Kobe and Hiroshima were affected Miyai (1995). The knock on affect of this is an increase in pollution and energy consumption.

Another issue relating to the external environment has been the negative reaction of new products and variants that have appeared at an ever increased. At one point, this was an attraction to consumers but they are now confused by choice and can become disillusioned at the fact that new products become obsolete almost as soon as they have been purchased.

The main internal environmental factor that affects lean production is directly linked to the workforce. There are problems with the ageing of the workforce and the increased difficulty of attracting the younger personnel into the companies.

Older workers tend to be less productive and versatile, along with increasing the companies wage bill. A good example of where this has been overcome is the Nissan automotive plant based in Sunderland (UK). The plant was built on a green field site and was therefore able to recruit a young flexible workforce. The younger workforce enabled the company to achieve high productivity and become one of the most efficient workforces in Europe.

2.6.2 Case study: cross section of manufacturing practice in Japan Katayama *et al* (1996).

There have been a number of case study investigations into the Japanese manufacturing industry, concerning the application of lean production and its associated methodologies. These investigations were carried out in 1995 and four plants were studied through a visit compromising of a plant tour together with a separate question and answer session. The questions covered four aspects:

- The extent to which production systems have been modified to accommodate any changes in the company in terms of; technology, software and human resources.
- The current state of development concerning lean production and related methodologies i.e. Total Quality Management and Total Preventative Maintenance

- The company's current competitive strategies and how they have been influenced by external and internal factors and conditions.
- Company's future plans with regard to production.

The four companies selected for Katayama's study were from a broad industrial background. These were; automotive, electronics assembly and appliance manufacture. These cases could then be considered as fairly representative of the spectrum of Japanese manufacturing industry.

Plant A - is a final assembly plant of a major automotive manufacturer. Its particular features include the following:

- Due to reduced demand, shifts are stopped twenty-five minutes early. Operators then carry out housekeeping duties for the remainder of the time.
- There is a trend towards job rotation among assembly line workers and office staff. This can create multi skilled workers and also improves job interest.
- As part of Kaizen activities, operators are provided with support to enable manual assembly tasks to be carried out more easily and efficiently.

Plant B – is a manufacturer of printed circuit boards for electronic telecommunications switchboards. The PCB plants operations are as follows:

- There is a need for a technological solution to the problem of producing small batches economically, although manual operations cannot be avoided.
- Owing to the wide finished product variety of special boards, there is a need to focus improvement activities on upstream products and processes such as bare board design manufacture and logistics planning.
- Batching together similar products is a means of increasing the resource efficiency of flexible systems.

Plant C – is a manufacturer of domestic refrigerators. The particular features of plant C are:

- Efficiency is reduced due to the mix production – this is counteracted by reducing set up time. TPM is extensively used to improve assembly efficiency and parts kitting is one of the improvements made.
- There are concerns that an increase in product variety will make the assembly process less efficient.

- Assembly lines are balanced by varying the spacing between refrigerators. This will allow the completion of assembly on larger work content stations.

Plant D – is a manufacturer of domestic air conditioners. The plant produces 40 models of air conditioner. Particular features of plant 'D's operation is:-

- The production rate is varied throughout the year. The plant has ten large warehouses for stocking finished goods to allow for seasonal demand.
- Assembly is 100 per cent manual to allow the plant to be adaptable. Automation could be introduced and costs reduced, but the company policy is to offer a wide and distinct product range.
- The rising value of the yen has meant that the home market is under threat from imports. This is due to overseas sister plants production cost being half of that of plant D. In order to compete, production costs should be reduced.

When analyzing the case studies, each plant has developed a unique approach to the design of its production systems. They have highlighted a number of problems, for some of which solutions have been found, while others remain to be resolved.

Plant A has falling domestic sales and plant B is due to the proportion of specialized products sold in small quantities, while plant D is due to seasonal sales and, again, the supply of its products from overseas plants.

Plant C's demand is more predictable, although problems are highlighted as its mix of products increases.

The key to all of these is to make the assembly process flexible and adaptable. A particular weakness of lean production is its inability to accommodate variations, or reductions in demand for finished products, which will often take production to below the break-even point.

When comparing a local company with the above, it is possible to draw comparisons even though there is a difference in the product and the level of mass customisation. The main problems lie within the cost of production in comparison to that of competitors who are located abroad. English sterling is particularly strong at present, which makes it difficult to compete in direct labour costs. In addition to this there is the issue of less efficiency due to the amount of customisation / product variety.

2.17 Adaptable production.

Adaptable production is a direct competitor to lean manufacturing. It is an essential feature that enables production to remain profitable over a wide range of demand situations than lean production. It has lower fixed costs and higher variable costs than lean manufacturing Katayama (1996). In order to vary production cost it is usually necessary to adjust the amount of direct materials and labour, but adaptable production will also build in the ability to be volume flexible. The use of flexible machines leads to high fixed costs, thereby reducing the adaptability of the system. The use of manual operations can make production systems both flexible and adaptable. However the argument of using manual labour is that it will result in lower productivity and quality than when using automated machines. However, the intelligent use of systems to support the manual work can often raise the productivity levels close to that of automated systems, while appropriately designed tools, fixtures and 'failsafe' techniques can help to achieve high levels of quality performance. High product variety can be achieved without necessarily embarking on completely new designs Hill (1991). Standardized modules of established and reliable design can be incorporated into new products, allowing greater mixing of products within an uncertain demand environment. Mix production allows a variety of products to be manufactured without large inventories. To minimise inventory losses during manufacture, the sequence of products needs to be carefully planned. Adaptable production allows the change in product mix requirements to be re-planned quickly to avoid inefficient operation. One way, in which a new sequence can be tested, is through the use of 'simulation' models.

The benefits of lean production are often achieved not by the underlying system, but by the associated improvement techniques and methodologies Hill (1991). These improvement techniques are not exclusive to lean production; they are equally applicable to adaptable production and should be rigorously applied to ensure that it remains competitive. This is detailed in figure 2.14

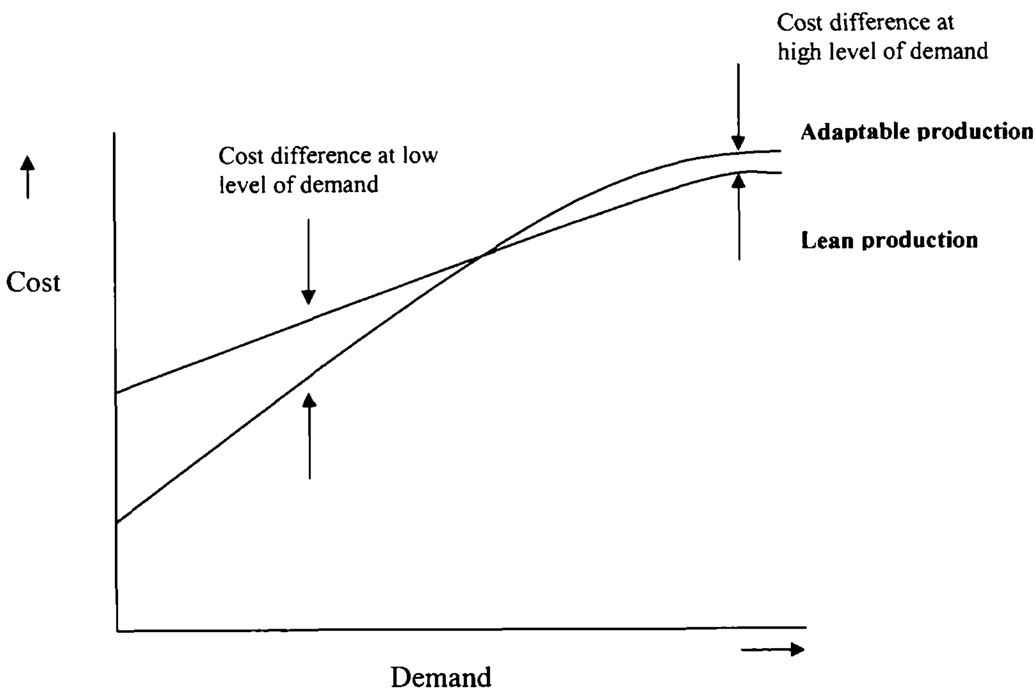


Figure 2.14 Lean Production Vs Adaptable Production Cost Curve

The above graph as devised by Katayama (2000) shows the difference between adaptable and lean manufacturing relative to cost and demand. When analyzing lean production when demand is low, the there is an increased cost, whereas adaptable production is more cost effective. However, when demand increases, the lean production costs reduce, while the adaptable production costs increases. Therefore it would be fair to summarise that when production is low, adaptable production is the better strategy to undertake. When production is high, lean manufacturing is the preferable strategy.

2.18 Six Sigma – A process improvement method as applied by Cummins Inc.

The six sigma process is an improvement methodology that can drive significant, measurable improvements, when:

- There is an identifiable improvement objective
- Improvement can be achieved in a four to six month time period
- There is significant financial impact

Six Sigma uses five main areas, which helps to guide the project through to completion. These are:

- Define – what the problem is.
- Measure – the extent of the problem
- Analyse – data and information
- Improve – implement to process
- Control – process to ensure that improvements are upheld

Through the introduction of Six Sigma, it is possible to improve performance in all areas of a company by implementing the following best practices. These are:

- A project selection hopper process that involves the process owners delivering clean project charters to belts.
- A sponsor accountability forum is in place
- Work plans that identify / quantify Six Sigma work for each team member
- Frequent and effective sponsor and master black belt reviews
- Key overall Six Sigma "health measures" are control chartered
- A system to rapidly disseminate and implement best practice ideas / projects

Black belts (full time employment change agents) are co-located where practical

- Process mapping and cause and effect matrices are used to identify and to prioritise business improvement activities
- There is a strong connection of business level goal tree to individual performance cell objectives

Six Sigma uses a project tracker to ensure that all areas within the project are on course for completion. An example of which is shown in figure 2.15.

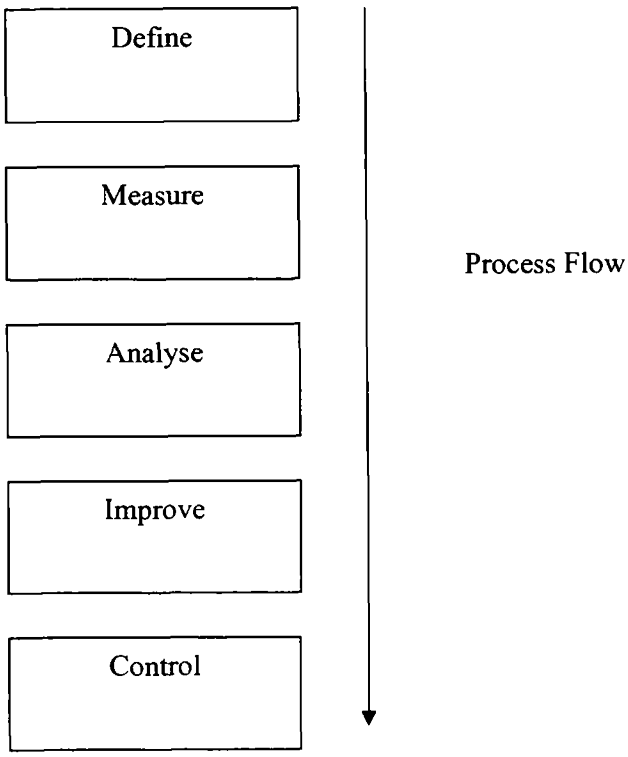


Figure 2.15 Six Sigma process flow

The above project flow diagram summarises how the six-sigma process operates.

Six Sigma methodology can be used as a process improvement paradigm within a large range of manufacturing strategies' whether it be lean, mass production or mass customisation.

Chapter Three: Research Methodology

3.0 Introduction

The purpose of this chapter is to illustrate the development of an appropriate method of exploratory research, based on the issues discussed in the literature review. In order to establish a framework for new product introduction, current industrial examples of new product introduction in mass customisation were examined as case studies. The case studies were carefully designed to establish any casual relationships between the four pillars of mass customisation and qualify their impact on existing production processes through the analysis of real world data.

3.1 Project Scope

3.1.1 Strategy

The topic of both case studies was the introduction of a new engine variant into the assembly plant, the engine being a mass customised product designed specifically for the customer. The proposition behind the first case study was to determine how the requirement for mass customisation affects production strategy (process amenability). The areas that were investigated were (i) fundamental changes in the engine design i.e. the change required to the existing production process (ii) customer demand – when the customer requires delivery of the engine, in line with pre-agreed timings. (iii) Marketing forecasts – what changes are required within the existing manufacturing environment to meet projected engine volumes. The new product introduction process was studied in order to gain an understanding of how a company operates with a new product introduction strategy for mass customisation.

In addition to this, the production strategy was analysed along with the associated running costs to ensure process capability.

The second case study investigated the organisational effects on the introduction of an electronic diesel engine into an existing production environment (DFEE). This new product was fundamentally different in design to the product currently being assembled at the plant. The changes included;

- Rear gear train arrangement
- Increased crankshaft length
- Structural and non-structural cylinder block design

- High pressure common rail system
- Four valve cylinder head
- Full authority electronics

3.1.2 Motivation

The logic behind this second case study was to determine how the scale of the project – far bigger than the introduction of the agricultural engine affects the strategy for planning mass customisation process. Studying these two examples of new product introduction in a mass customised environment of such differing magnitude, it was possible to understand if there were any fundamental changes between small and large capital investment projects and the framework to be used.

3.1.3 Exploitation of Results

A generic framework will be developed for mass customisation by analysing and evaluating both case studies and the information detailed in the literature review. It will be important to carry forward the key elements that make up a mass customisation strategy in order to formulate a framework tailored for an existing environment. The framework will not detail the step by step execution of a project, but will focus on the 'critical few' that must be considered in order to meet the project deliverables. The framework may need to be developed, due to the fact that each project has a unique feature that requires different methods of work and processes. If successful, the suitability of the framework can be put forward as a viable alternative to be piloted in future new product introduction projects. While it is accepted that developing the framework from only two projects is limited, it may be that further testing be tried beyond the scope of this project.

3.1.4 Data collection.

An initial reference framework was established through the literature review and informed the type of data gathered. Two case studies were used to quantify the theory documented in the literature review.

3.1.5 Data Analysis

Once the data had been collected, it was analysed by drawing comparisons between product activities observed during the data collection and the four pillars of mass customisation. These will form the basis for the framework and are detailed below;

Pillar 1; Customer sensitivity – *the areas that have most variability – creating effective presentations from which customers can make informed choices* Hart (1995). A good example of customer choice was observed in case study 1, where the number of fuel pump ratings available on an engine from which a customer to choose was vast. When investigating further, there was a whole array of customer options made available by the marketing group at the beginning of the project. These were offered to customers so that they had an input as to the tailoring of the product to suit their own individual needs. In some cases, components were specifically designed to suit the customer application. A good example was the oil pan on the structural product that was integrated into the chassis of the tractor. It was evident that this was a beneficial strategy undertaken by the company in order to fully integrate the products into a customer application and was a major selling point when tendering for the business. It was then up to the company to integrate the component design into the existing process by making it more amenable.

A second area where customer sensitivity was observed was in the shipping of the engine. The customer was given the choice of whether the engine would be delivered on a metal returnable skid or a wooden non-returnable disposable skid. The advantage to the customer choosing the latter option would mean that there was no responsibility in delivering the skid back to the supplier. However, this was more expensive over time and less environmentally friendly. Again the customer was given the options from which they could choose. This may be at a cost to the company but can be the difference between gaining and losing business. It was highlighted in the literature review that mass customisation is not an easy strategy to implement and ultimately has a significant cost.

The second case study was different in that the new product introduction was driven by emissions legislation and not customer requirements. A fundamental change in the design of the engine, moving from a mechanical to an electrical set up, opened up another host of options from which the customer could choose. These included various engine management software specifications to control the engine speed and fuel ratings. There was a lot of work required to ensure that the infrastructure was in place prior to the engine launch. The engine management systems alone were a significant capital investment with both the hardware and software required for every engine. An important part of the new product introduction was to ensure that the customer base was aware of what the changes were the impact on cost, installation and delivery. Secondly, why they were happening and the necessity to change to meet highways legislation? The job of the customer accounts team was to visit existing and prospective customers to promote the requirement for change and educate in the new technology available.

Pillar 2; Process amenability – *the multi faceted area, compromising enablers, marketing and strategy, design, production and distribution* Hart (1994). The process amenability for both new product introductions was required from all departments from concept through to final design and production. There were some good examples of this observed in both projects and common themes throughout. A fundamental floor in each project was that they were both launched 'late'. This was due to a delay in financial approval. By this time, production readiness dates were already defined, in the two case studies, one by the customer, and another by emissions legislation. This created a problem that if a project does not start on time and there is little margin for error within the strategy, it was increasingly difficult to 'catch up' and deliver within pre-agreed time lines. In both projects the problem occurred whereby the manufacturing department had a reduced amount of time to implement process modifications due to the fact that the project started late. In the smaller product introduction case study, the process was not fully capable after the engine launch date. It was particularly difficult to rectify the situation, because there was not much focus on the project and therefore less urgency to close the outstanding issues. A key learning from both projects was to get the project started on time in order to allow all stages of work to be completed in readiness for production start up.

When analysing one of the new product introduction projects, it was interesting to understand the interaction between functional departments to understand the positive impact this may or may not have on providing the customer with a quality product. Within both projects it was expected that functional departments had good communication flows and strong cross functional departmental interactions. It is documented within the literature review that strong communication is essential when introducing reduced lead time new products.

Due to the magnitude in size of both projects, there was a difference as to the level of communication required. The first project relied upon a number of individuals communicating among one another – a relatively easy concept compared to that of the latter project. This demanded 'whole' departmental cross functional discussion and communication. This would ultimately increase opportunity for error.

Pillar 3; Competitive environment – *forces that could enhance or detract from implementing a mass customisation strategy* Hart (1994). It was necessary to gain an understanding of the factors that directly impact on new product introduction projects and to highlight which factors need to be built into the framework to ensure effective mass customisation capability. By examining the two case studies, it was necessary to understand a) if there was a requirement to have a mass customisation strategy and b) what the advantages were (if any) in achieving a successful product introduction.

When observing case study one, it was evident through the unique form of engine components, that the product was custom designed. A good example of this was the oil pan, designed to form part of the tractor chassis. It was necessary to make hardware changes to the existing assembly process due to the unique design of the sump. A rigorous costing exercise was carried out to ensure that project expenditure stayed within budget and to ensure that any on-cost to the customer was not too high. The ability to accommodate requests from the customer, while having a flexible existing process, was an important factor in winning new business.

The one major disadvantage of undertaking a strategy like this was the increase of physical inventory due to the proliferation of parts. This could impact on the companies' ability to de-expedite material and meet inventory turns which would adversely affect costs. Again, this is something that should be carefully considered by any company wishing to undertake a mass customisation strategy.

One thing that was common across both projects was the headcount involved in managing the number of options available within the company mainframe. There was a tremendous amount of work involved in maintaining, updating and obsolete stock. Even with state of the art software management systems, there was still a requirement for people to effectively manage the process. The company observed had another two and a half thousand shop orders beyond the scope of the two case studies, the majority of which have different components and options to manage. It must therefore not be under estimated as to the amount of resource and support required to effectively manage the material logistics and customer options process. From the infrastructure of the observed company, it was evident that there had been many years of development in the procedures and systems used to control the customer option portfolio. This is a system that is continually being improved using cost reduction activities, in particular Six Sigma. A company would surely have to be absolutely committed to implementing a mass customised strategy into their organisation, given the complexities observed in the two case studies. There would have to be a thorough business case based upon the need of existing and prospective customers.

Pillar 4; Organisational readiness – *a tough and honest assessment of a company's attitude, culture and resource* (Hart 1994). The same company was used in both case studies; it was therefore not possible to compare two different companies. However, it was beneficial to assess some of the company's attitude, culture and resource in order to test the framework. This involved looking at issues that directly impacted the project and how they were addressed, the resource that was employed to achieve key tasks. As with any project, there would be issues and it was therefore interesting to understand the different countermeasures used throughout the project. In particular, what tools and processes were used to direct the project through to successful completion?
Data was collected externally through observations and by working with the new product introduction teams.
In addition to the reference framework, the following data was collected;

- Working with a cross functional new product introduction team in engine assembly – who was involved? What was their role within the team? How did the teams interact in order to achieve best in class results?
- Key milestones within the new product introduction teams – at what point did they occur? Were they on time? If not, what were the factors that had a negative impact?
- Length of time of the project from concept through to the production readiness stage?
- What are the typical lessons that can be learned?

- Is there anything that could be incorporated into the framework that could be beneficial to future projects?

When observing the companies approach to new product introduction using the two case studies, it was evident that there was a common set up in terms of personnel and departments to cover the required work. Due to the differing magnitude in size of each project, there was a correlation in the number of heads assigned – the more complex the project, the more resource required. For a small company looking to undertake a mass customisation strategy for large scale projects, this may prove to be expensive in terms of hiring additional staff and uneconomical based upon the return on investment. The second case study is a good example of the vast array of personnel and teams involved for the introduction of a new product platform. Not only was there specialized personnel assigned to the projects, but whole departments formed to coordinate and execute the project introduction.

When considering the companies attitude towards mass customisation, there were some clear expectations that were evident within both case studies. These are listed below;

- Time to market – in line with customer requirements
- Within budget – in line with companies financial model

Both were adhered to with great discipline in order to meet the project deliverables.

Formal management reviews took place on a regular basis at strategic stages of the projects, the purpose of which was to evaluate performance against plan and highlight any issues that could jeopardise the new product introduction. This required buy in from the highest level within the company, up to and including senior corporate management.

The work required to complete both projects is summarised in each case study and therefore gives and accurate understanding as to the level of work required in undertaking a mass customisation strategy.

3.2 Mass Customisation Integration in an Existing Environment

In order to further support the information detailed in the literature review, it was necessary to select a company for study who have good experience of engine new product introduction into an existing mass customised production environment. This would further enhance the understanding of the key milestones and time frames to be included for successful product introduction.

The information detailed in the methodology section is collected from the time spent with a company currently undertaking a mass customisation strategy and observing new product introduction strategies and processes. A top level summary of the company's strategy is included below and gives an interesting insight as to the 'forward thinking' and careful planning required to implement new products into an existing environment.

3.3 The Value Package Introduction Process

The value package introduction process used by the selected company and is particularly tailored to the company's strategy. It was developed over many years of manufacturing experience and encompasses different elements that make up the complete requirements for a new product introduction. It is for this reason that the Value Package Introduction process will be used as a starting point to help develop a mass customisation framework. It was important to understand the flow of the VPI process along with the key milestones. The purpose of the Value Package Introduction (VPI) process is to ensure the smooth transition from concept through to a finished manufactured product. It documents the key areas that need to be addressed and in particular guidance to the following functions;

- Marketing
- Design
- Quality
- Manufacturing

The VPI process is applied at all stages of the new production introduction process and in particular, five key stages that are evaluated in Management reviews. The reviews are strategically called at key stages to evaluate project deliverables and ensure the project is on plan. Figure 3.1 shows how each business unit is linked to the VPI process:

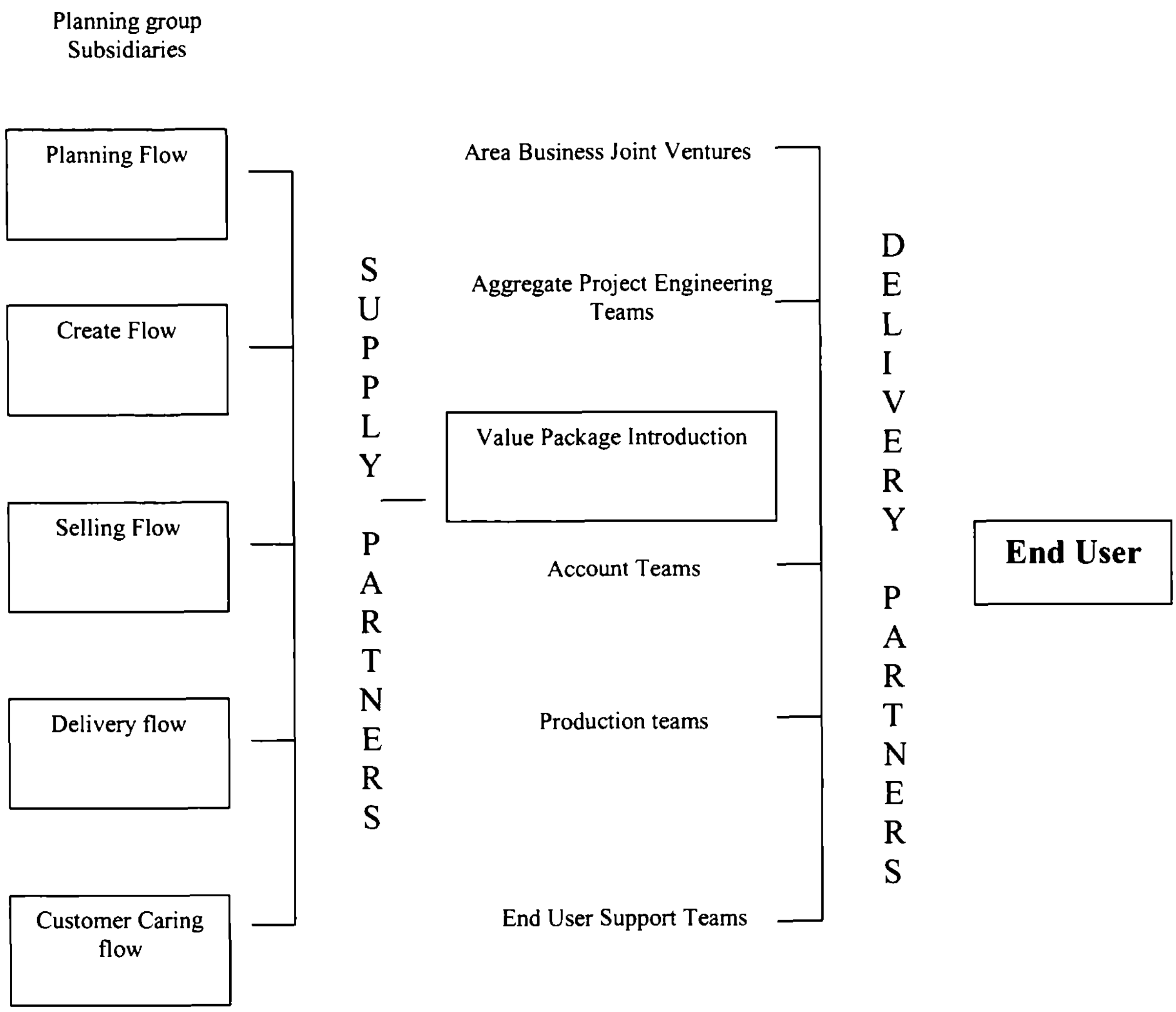


Figure 3.1 Business unit interactions within VPI process

As illustrated in the above chart, the value package introduction process is identified as a key link between the supply and delivery partners. Each subsidiary has a strategy of its own and is designed to be focused towards a Mass Customised environment.

The VPI process focuses on the full value of the package and not solely on the product. This is also better aligned with flow and functions, with upstream flow integration for planning. There is also downstream readiness, which includes the sale, delivery and after sales care. In addition to this, there is a focus on effective interactions of the team and also the management review group and functional management. Areas of particular focus are the application of cycle time principles and more discipline through tracking evidence of work completed.

Understanding the Management Review Process

The Management review process was used to track all major project issues through to completion. It also gave an insight to issues that could potentially impact on the time period of the project and what countermeasures were required in order to deliver the project within the agreed timeframe.

There are many different areas that were considered throughout the review process. These are detailed in figure 3.2.

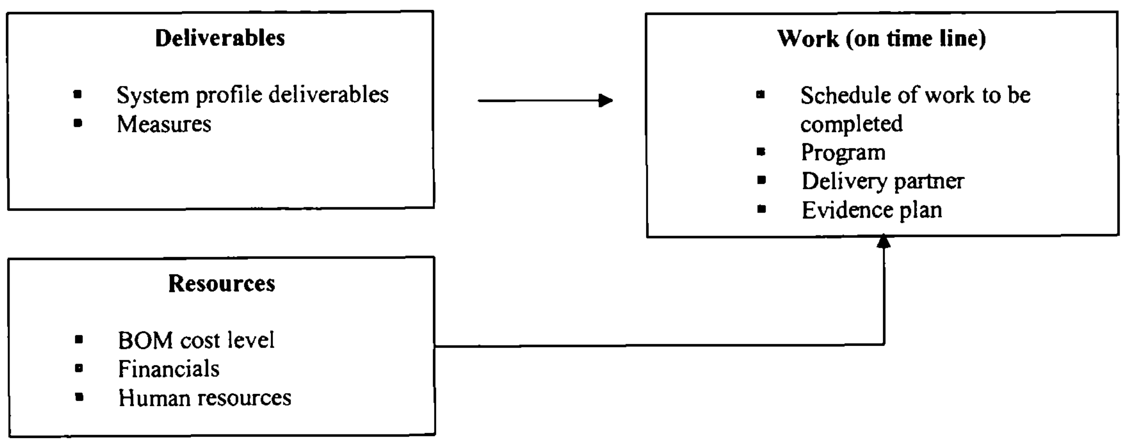


Figure 3.2 Management Review Considerations

The flow diagram detailed in figure 3.2 gives a good overview as to the key elements that need to be considered when delivering a new product introduction program. These have been split into two areas; (i) **Deliverables** – what are the key measures to be set up within the project in order to track to project completion. A good example of this is budget tracking, a key deliverable in ensuring that the financial targets within a project are met. (ii) **Resources** – Who are required in order complete the work within the allocated time. A good example of this is the introduction of a new engine in order to meet emissions standards. The introduction date for emissions legislation is set by external bodies, thus proving that some factors are not directly controlled by the company. Resource levels can be dictated by the capacity of the company (internal) and also the level of demand from the customer (external). The level of work is dictated by the complexity of the product, which, in this case is dictated by the emissions requirements – an external influence.

The more complex the product, the more work and resource is required. This will potentially have an adverse impact on the overall cost of the project and is demonstrated in figure 3.3

New Engine Design and Manufacture to meet emissions legislation

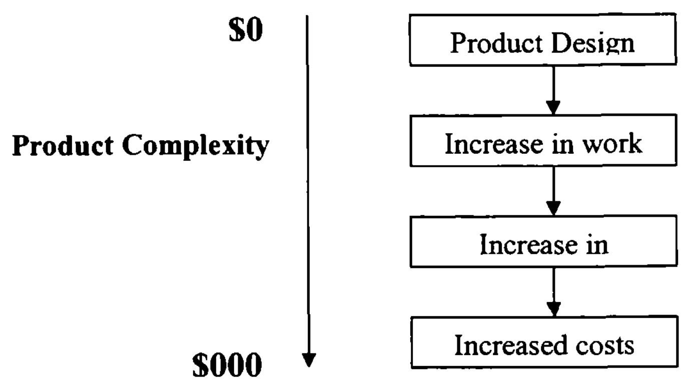
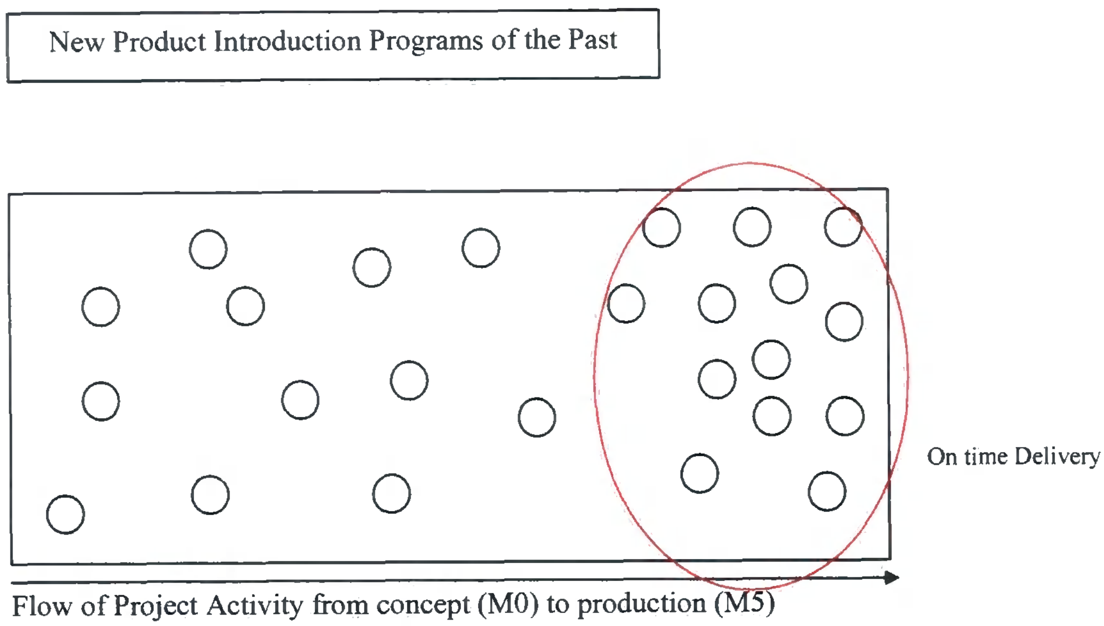


Figure 3.3 Product Complexity

Figure 3.3 shows how a typical new product introduction program can be compared to the VPI program in terms of project activity and time to market. Each circle represents a project activity at a given point in time. The ultimate aim, as with every new product introduction is to ensure that the project is delivered on time and within budget.



It demonstrates milestone slippage where the majority of the work is completed at the end of the project

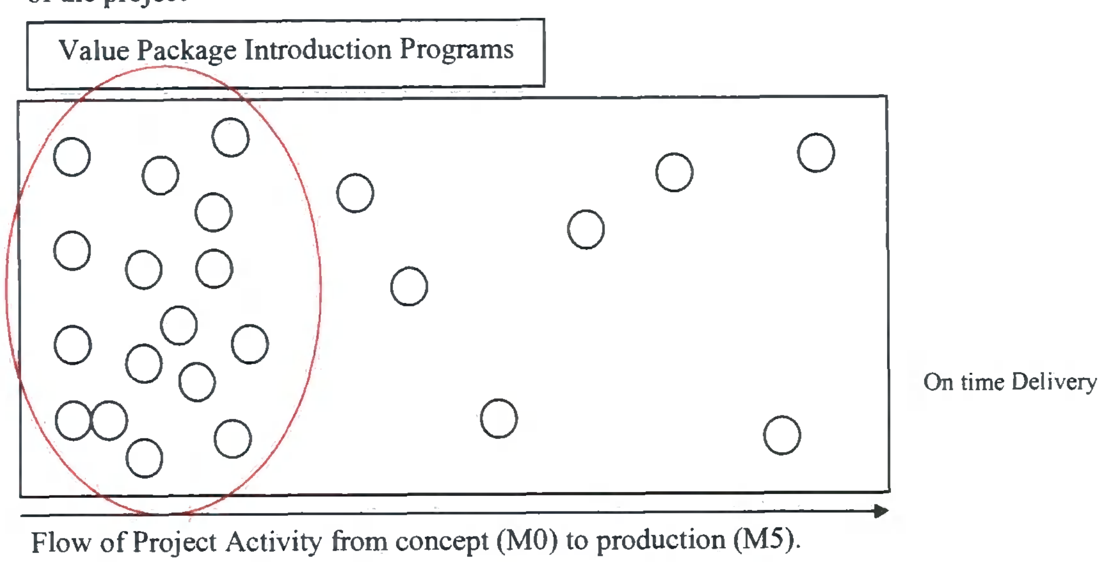


Figure 3.3 Value Package Introduction Activity

Figure 3.3 shows that Value Package Introduction (VPI) project activities are clustered at the beginning of the project. As demonstrated in the two diagrams in Figure 3.3, the majority of work undertaken in the early stages of the VPI program work. This is because the traditional introduction strategy was not as structured as the VPI. Work milestones tended to slip and the majority of work took place at the end of the project. The VPI process follows the same principles of concurrent engineering in that project tasks are completed simultaneously at the front end of the project in order to achieve timely introduction. It is evident from figure 3.3 as to why there has been a transition to the value package introduction. Based on the findings of the two case studies, it was possible to analyse the literature theory with respect to that of the mass customisation strategies employed to develop a more comprehensive strategy. The VPI strategy used in the two engine introductions can be summarised in Figure 3.4:

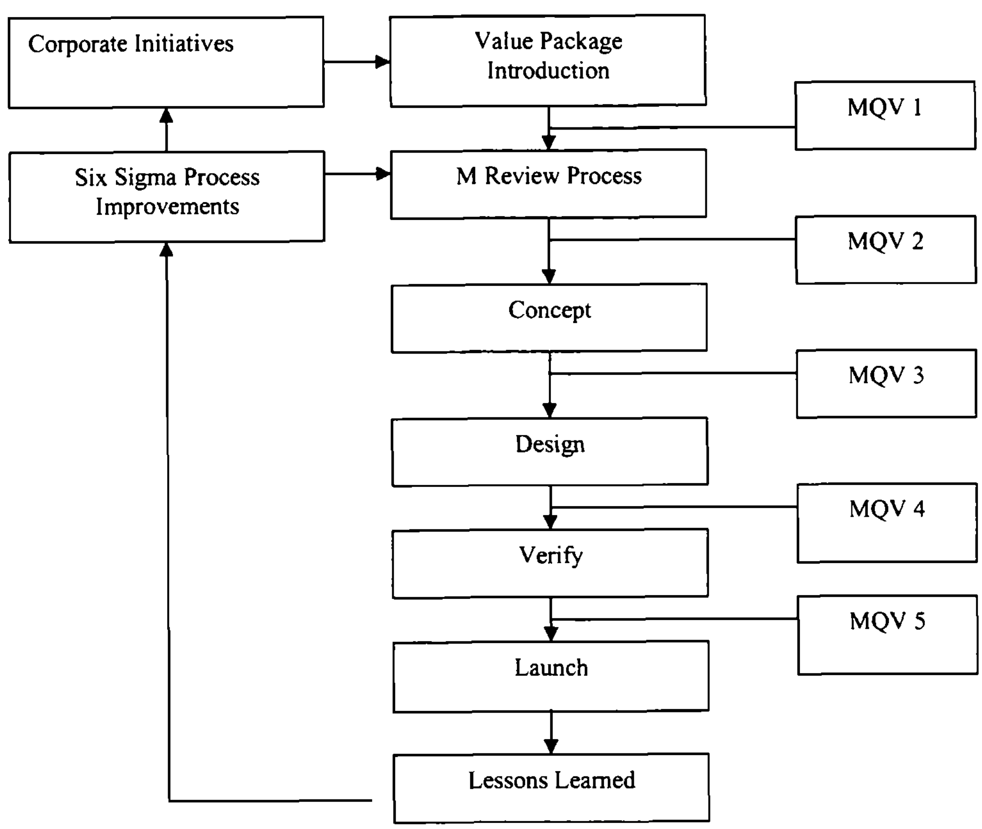


Figure 3.4 VPI Strategy

The VPI diagram detailed in Figure 3.4 describes the strategy for new product introduction. The Value package incorporates a series of management reviews that are used to evaluate the projects at key stages. These are listed in the diagram as; concept, design, verifies and launch. The project is then reviewed in the 'lessons learned' section. The management quality verification (MQV) sessions precede each management review in order to establish whether all quality processes are being adhered to. Design for Six

Sigma projects may then be deployed to improve areas within the strategy that are not coherent.

It is evident to see that the current value package introduction process employed by the company is at the hub of all activity in terms of concept manufacture, supply and delivery of new products.

When analysing the framework and procedures used by the company, it was important to highlight all of the key activities that took place in large and small new products this would provide a greater understanding of the effects and outcome of each project. Elements of the companies work flows and procedures were observed in order to identify common milestones that helped to form the basis for a framework for mass customisation. As previously discussed, the purpose of the research is not to create a list of procedures or rules but to identify the key common milestones that may be considered in order to meet project deliverables in a mass customisation environment.

3.4 Conclusion

There are some common themes that have arisen when considering the framework methodology. The first and arguably most important area is how well the companies' objectives fit into the 'four pillars' of mass customisation? It is vital that all areas need to be considered carefully and implemented in line with the companies' new product introduction strategy. If a company were not to undertake a comprehensive approach, then mistakes could be made, costs could rise and ultimately projects could become on profit making and the viability unsustainable.

There were many examples within each mass customisation pillar that highlighted 'real life' issues encountered on each case study detailed in Chapter 4. These were not easy to overcome and some required significant capital investment in order to deliver the project on time and meet customer expectations.

The issues are highlighted and discussed in greater detail throughout both case studies which will enable a greater understanding of the fundamental elements when undertaking a mass customisation strategy

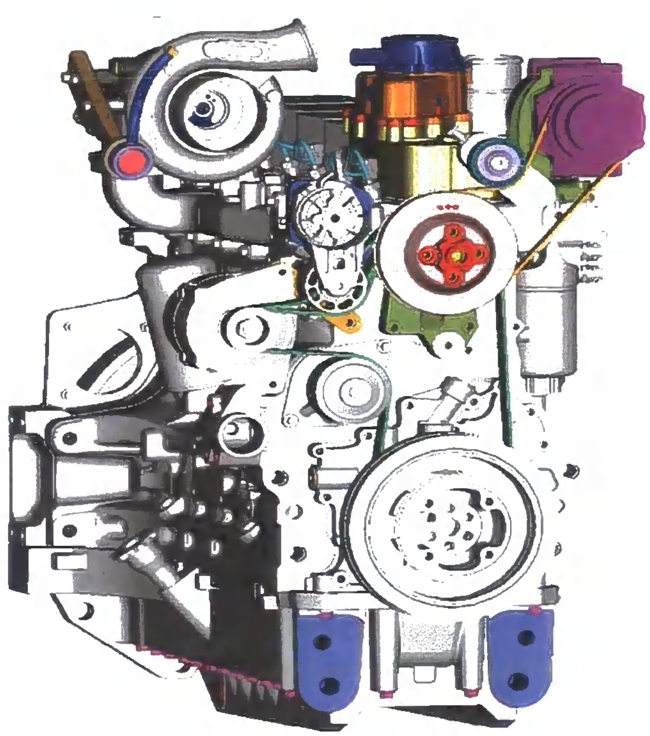
Chapter Four: Case Study – Introduction of Agricultural Structural New Product

4.0 Introduction

The purpose of this chapter is to observe some real life mass customisation new product introduction projects. It is important to gain an understanding of which factors should be considered throughout the course of the project in order to deliver positive results. Critical milestones are highlighted in each project along with problematic areas, including areas for further improvement.

The observed case studies are both from the same company but of differing magnitudes, both in terms of capital investment and the number of personnel involved. Importantly, the implementation strategy that was followed is very similar. This allowed for direct comparisons to be made between each of the projects and enable a greater understanding of the good and bad elements within the strategy.

As discussed, both case studies are from the same company and although limited, are realistic when considering the scope of the project and the specialised subject being investigated. The first case study is for the agricultural engine seen below. The second is for the electronic engine seen later.



4.1 Strategy

The strategy for the implementation of the agricultural engine was unique to the engine assembly plant. A joint venture was formed with competitors to jointly develop and market an engine exclusively for the Agricultural market. The members of the joint venture were all manufacturers of diesel engines and are direct competitors in business. A production network was engaged in the design, development and manufacture of the product for Tractor applications across Europe and North America.

Production networks can be described as the 'mutual use of resources and the joint planning of the value added process' Wiendahl (2004).

The ASB product was customer driven and required both a four and six cylinder product to tailor the needs of the application. This factor is a key underpinning of pillar one of the four pillars of mass customisation that is 'customer sensitivity'. The company had identified a genuine customer need and pulled together a competitive package for the prospective customer. This included a product specification that structured all of the necessary options required to assemble the product. This was offered to the customer along with costing information. A good example of one of the options offered was the several fuel pump ratings released to satisfy the need of the customer – this would allow the OEM offer their customers a greater range of choice.

4.2 Engine Design

There were several major changes in the design of the ASB product to that of the other engine variants that were being assembled at the existing manufacturing facility. The main changes were to the engine block, oil pan and transmission adaptor. The changes were mainly to the physical profile and weight of the components, which would prove to be a challenge for both logistics and assembly. This would test the organisational readiness (pillar 4) of the existing manufacturing facility and its ability to adapt within the existing environment.

4.3 Customer Demand

Sales and Marketing groups embarked on investigating the demand for the product and the potential forecast for future sales. It was apparent that there was a seasonal demand for Tractors throughout the months of June, July and August. This would prove to have an impact on the assembly strategy that directly impacts on process amenability (pillar 2).

This kind of volume would suite an adaptable production strategy as discussed in the literature review.

4.4 Constraints

There were many constraints within the project, some of which were customer driven and others were from within the company. These were as follows;

- Seasonal demand of engines for the tractor product (pillar 2). How amenable was the existing production environment to the introduction of new products with seasonal demand?
- Design of the engine and the impact it may have on the cost of the product (Pillar 3 – competitive environment). As with most other business sectors, there was a number of other engine manufacturers tendering for the business.

The internal constraints were;

- The financial budget limitations to enable production process capability (Pillar 4; organisational readiness) As with all projects it was important to ensure that it was financially viable to implement into the existing manufacturing environment.
- The project timeframe to enable production readiness (Pillar 4; organisational readiness) was it realistic for the company to implement the new project within the timeframe required by the customer?

4.5 Marketing Forecasts

The customer engine volume requirements were received to determine the type of strategy that should be undertaken. This could have far reaching consequences on the margin of the product and the ability to deliver engines on time. The marketing forecast for ASB product is shown below over a twelve month period in figure 4.1.

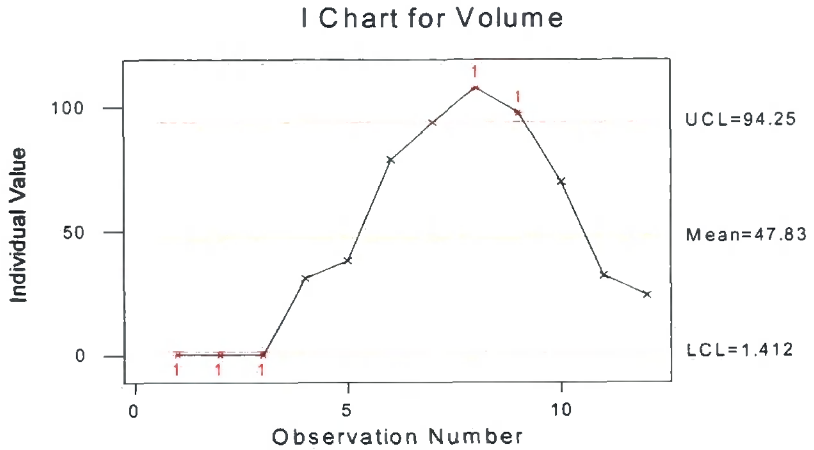


Figure 4.1 Structural Block Volumes

From this figure, it is evident that the peak for demand of engines was during the months of July, August and September. The seasonal demand would therefore directly impact on Inventory levels and therefore needed to be considered as part of the implementation strategy. From the information supplied by the customer, it was possible to develop a charter and contract to enable the new product process to begin.

4.6 Process Iteration

By observing the processes used for the introduction of new products, it was evident that new product introduction was required to undergo a process of iteration in order to define a concept that can be developed to a marketable product. Figure 4.2 was developed to summarise key milestones in the process from observations and discussions taken place in the management progress meetings;

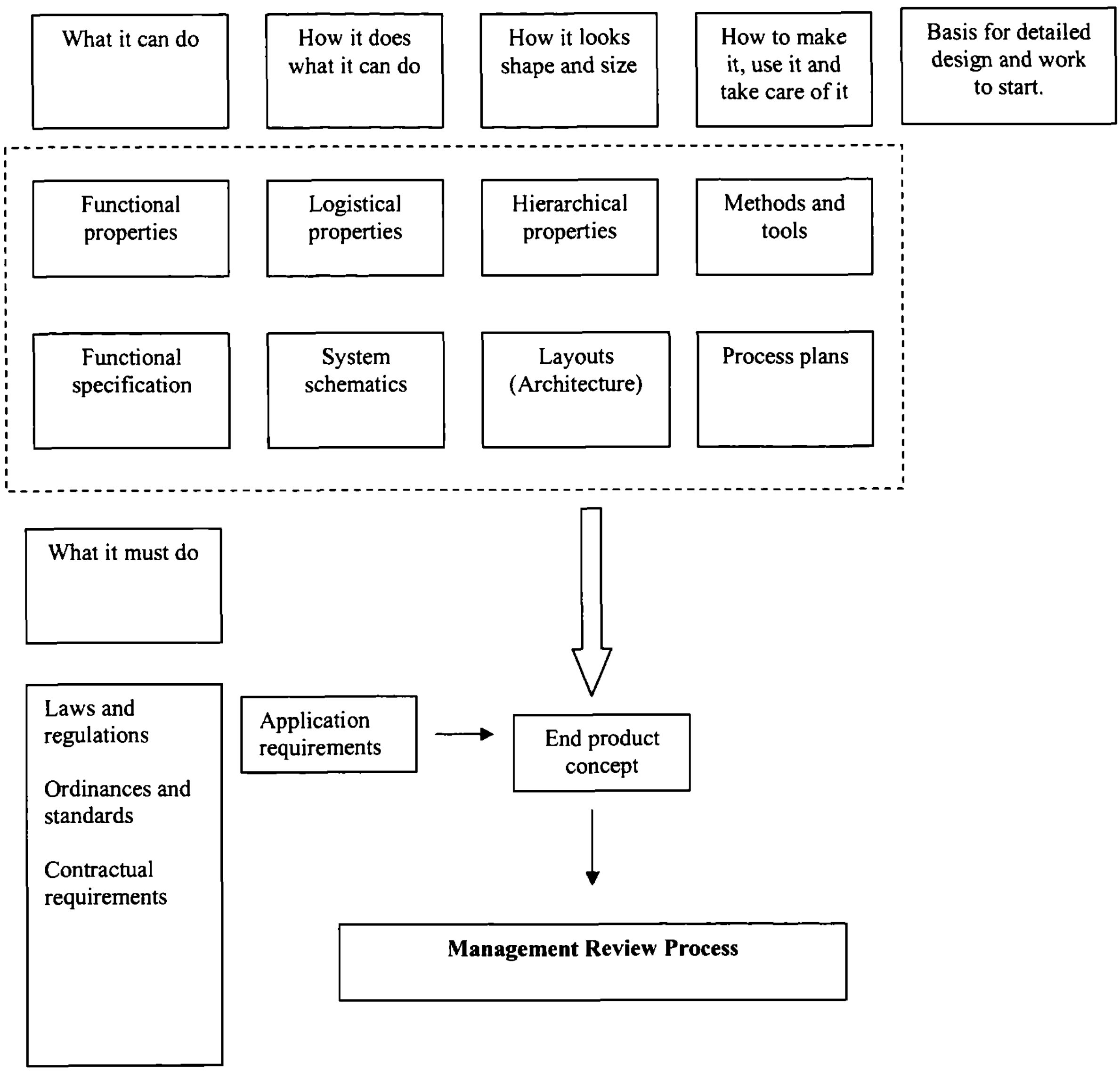
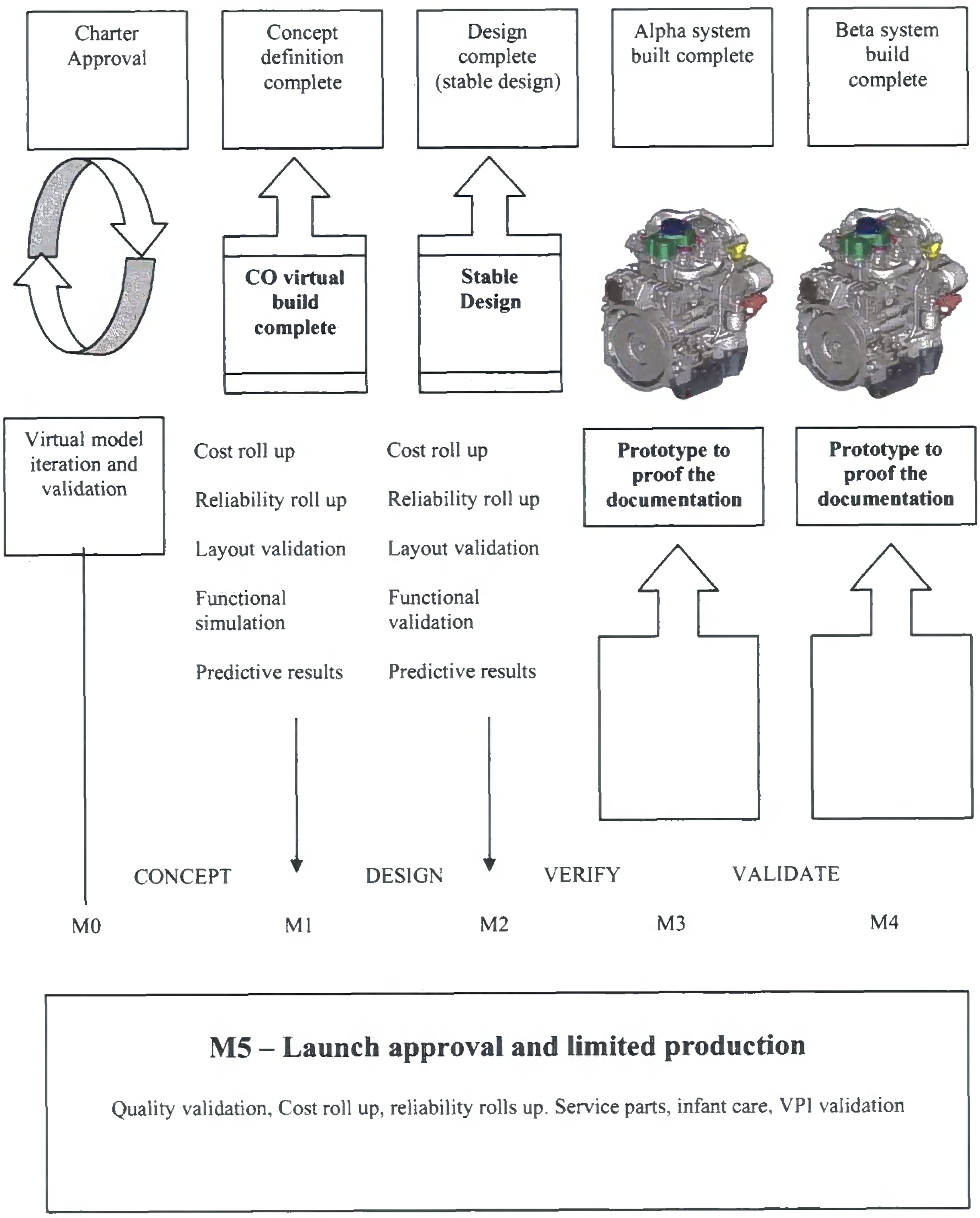


Figure 4.2 New Production Product Iteration

All of the elements that make up the flow chart were key to ensuring 'organisational readiness' and successful design and introduction of new products in an existing environment – hence ensuring the criteria of mass customisation pillar Four was met.

4.7 New Product Introduction Process

It was possible to observe the template used for the introduction of new products into the companies manufacturing facilities. A VPI (Value Package Introduction) team was set up to facilitate the introduction of new products. The VPI charter for the introduction of new products is shown below. At each stage of the process a management review (M review) was held. This is demonstrated in **Figure 4.3 the Management Review Process.**



Full explanations of the 'M' review process key stages with definitions are listed below. Each definition can be linked to a pillar of customisation. These are listed as italics.

M0 - is where the project charter is set. *(Customer sensitivity and Competitive Environment are two key areas that needed to be considered)*

M1 – is where the concept definition is completed and the virtual build complete. Cost and reliability roll up are complete and functional simulation and predictive results complete. *(Process Amenability)*

M2 – Is where the stable design is complete.

M3 – Is where the alpha build engine design is proved to be capable and a prototype assembled. At this stage all assembly issues are listed, additional tooling identified and training opportunities noted. *(Organisational Readiness)*

M4 – The beta build is the stage where the product is signed off and approved for manufacture. The assembly process at this stage is ready for production and operator training complete.

M5 – Launch approval – a limited production is initiated to finally prove out the process and eliminate any minor deficiencies. These are the first batch of customer engines, as they are assembled using production tooling and meet all manufacturing and assembly engineering standards.

4.8 Production Strategy

As part of the production strategy, it was important to consider the unique components required to assemble the ASB product. Due to the mass customised environment, this was important to consider so as not disrupting the production flow of current product. The existing production process can be best described in figure 4.3.

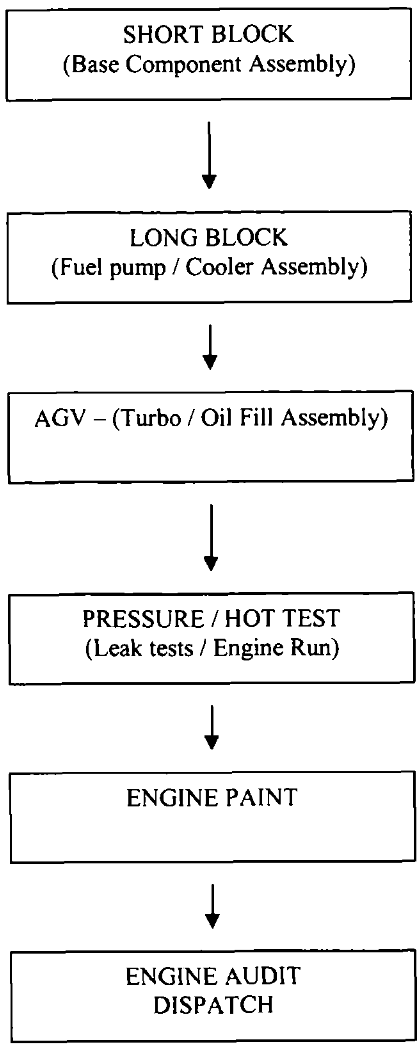


Figure 4.3 ASB Product Production Flow

The production process was split into different areas of responsibility as shown above, whereby the engineering cross functional teams have responsibilities for each production line. An example of the matrix team detailed in Figure 4.4.

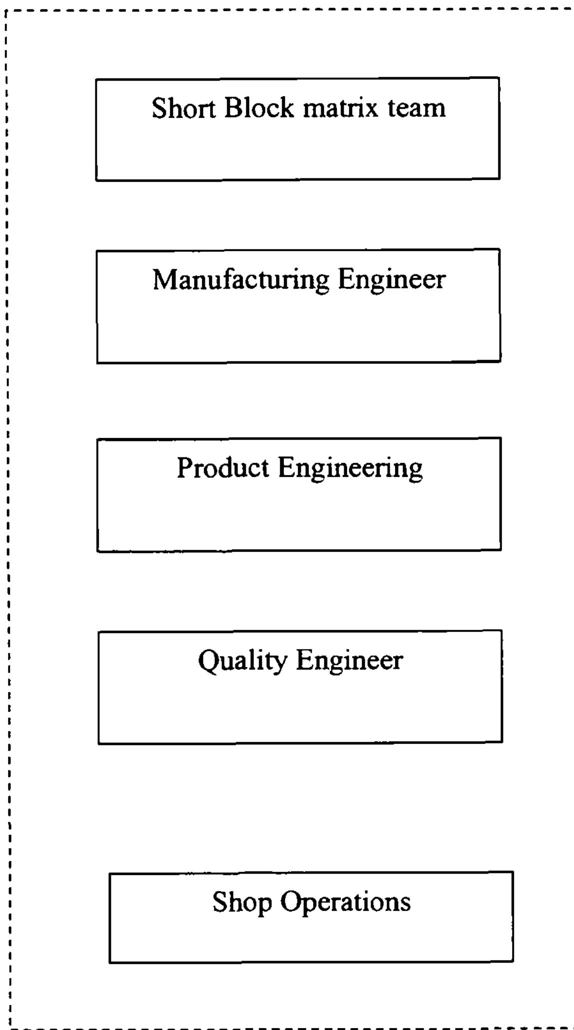


Figure 4.4 Matrix team structure

There are two and a half thousand Shop Orders produced on the same production line, all of which have a slight variation in their assembly. The matrix (cross functional) teams are designed to enable rapid support to all Engineering and Manufacturing issues.

The ASB product had several changes in design to that of all other existing products. These were;

- A cast Iron oil sump with different profile – this required $100,000 USD upgrade to transportation pallets within the assembly process
- Internal changes to the engine assembly process (tooling, jigs etc) – $12,000 USD

- Considerable increase in the weight of the engine components – this would have cost implications when considering the material logistics
- The most expensive modifications would involve the automated machinery. This would include the crank loader, piston protrusion measurement and block turnover machine.

But, could such costs be financially justifiable for such a low volume product? This question along with others would determine the viability of the project.

The proposal for the upgrade of the Short block production line would cost in excess of $1,000,000 USD with a six month lead time for installation and commissioning.

The second strategy was to introduce a cell build facility, whereby engines could be built to Short block level and then introduced into the Long block line. This would eliminate the need for the $ 1,000,000 investment to upgrade the Short Block production line. The following factors were associated with this strategy:

- Increase in headcount
- Additional floor space required to introduce the cell build area
- The use of manual measurement, moving away from the automated piston protrusion, crank end-float etc.

It was decided that due to the low volume of the product, such a large investment to upgrade the existing process could not be justified. The decision was therefore taken to assemble the engine offline and reintroduce into the Long block process.

4.9 Direct Overheads – Headcount *(Organisational Readiness – Pillar four)*

When considering the headcount requirements, it was important to consider the customer engine demand against the time to manually assemble an engine. It was then possible to understand the number of additional heads required to assemble the product. The new products development area was used to calculate the manual assembly time per engine. The key to the success of the cellular build strategy would be to utilize existing headcount from the Short block production line as required. This would save on training costs. The headcount requirement model is shown in Figure 4.5.

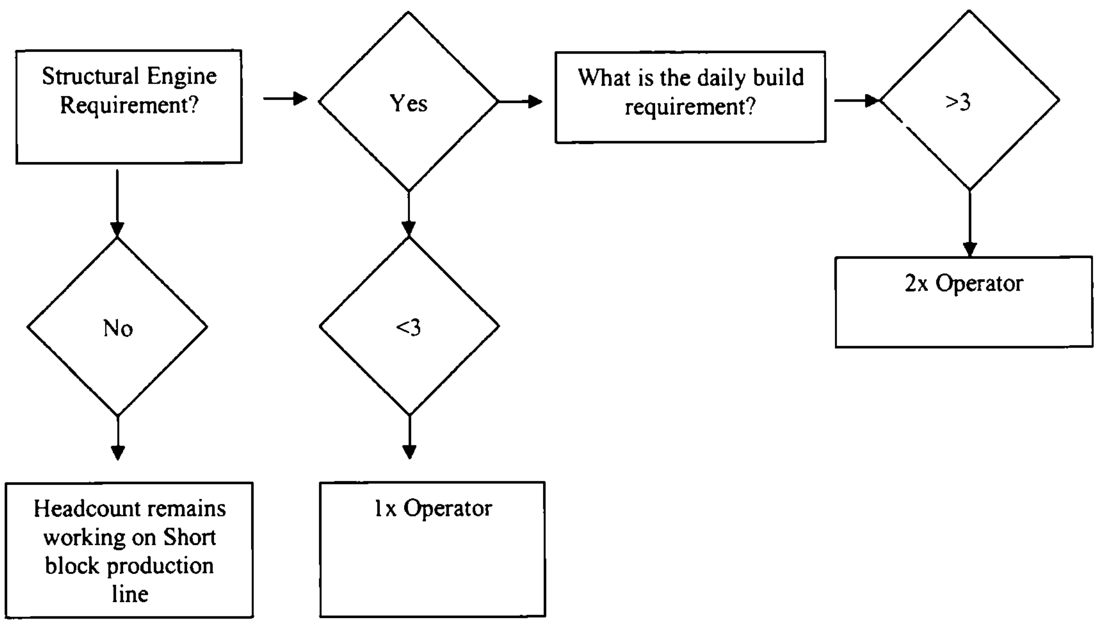


Figure 4.5 Headcount requirement model

4.10 Delivering Quality Products. (Competitive Environment – Pillar Three)

All manufacturing strategies should incorporate quality in every step of the process. When considering the cell build, it was important to understand all of the critical areas that could potentially compromise Quality during the assembly process. The areas that were considered are as follows;

- Connecting rod bolt torque
- Cam and Crank gear assembly
- Transmission adaptor bolt torque
- Oil pan bolt torque
- Lube pump assembly

State-of-the-art torque equipment was purchased to ensure that clamp loads in all of the joints were to the required engineering specification. A PLC was used to ensure that the engine assembly was carried out in a controlled sequence. Various software programs were created in the PLC to ensure that both the correct number of bolt torques was achieved. This would help to ensure that the product quality was of a high standard.

4.11 Long Block Assembly Requirements – Process amenability

Part of the strategy required was the modification of the Long block assembly process. All of the transportation pallets were modified to cater for the unique oil sump profile. This change was done as a rolling process, so as to minimise the effect on the current production process. The second major change on the Long block line was the cylinder head bolt torque. A new program was required to install the torque parameters. The cylinder head machine is an automated process that is used to bolt the head to the cylinder block. The parameters were programmed into the machine and trials were conducted to prove that the process was capable.

4.11 Summary

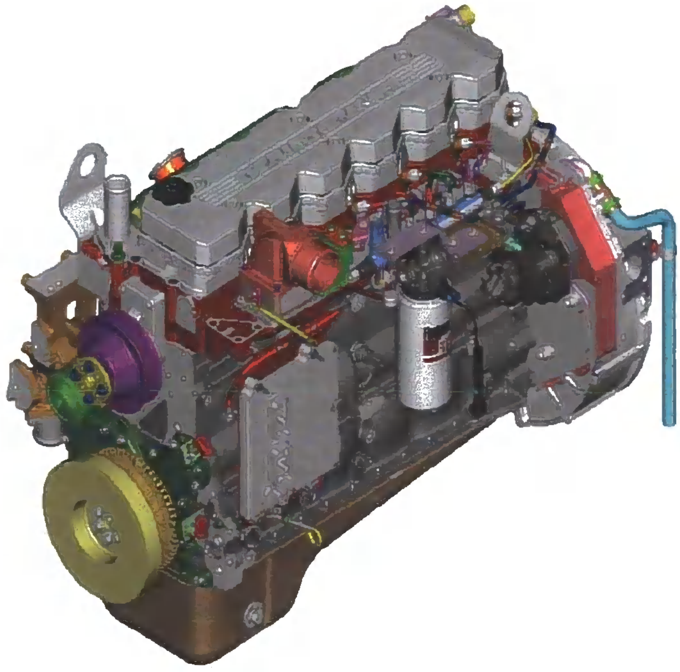
The cost to implement the ASB product into the existing production process was considerably less than that of the Electronic ISBe engine. This was due to significantly lower volumes and the expected revenue to be generated. When summarising the processes involved ensuring a successful new product introduction, it was evident that making the correct decisions at all points of the implementation process was key to a successful implementation. If the correct decisions were not made, for example; assembling the product offline, the cost of the product would have been adversely affected.

The methodology behind the implementation of the ASB product was to find the most cost-effective strategy in order to maximise the return on investment. It was important to ensure that there was no compromise on the fundamental values within the manufacturing strategy; these are quality, health and safety, productivity and cost. It was a customer requirement and expectation that the product was delivered defect free and on-time.

Chapter Five: Case Study – Electronic Engine Introduction

5.0 Background

The company detailed in this case study has been assembling and testing B series engines since 1986. In 1990 the assembly and test facility was modified to accommodate the C series engine. The customer base has since broadened and customer options have been increased. In order to comply with European emissions legislation, there was a requirement to re-design and introduce a new emissions compliant product; this was called the ISBe Euro 3 electronic engine, seen below. There was a requirement to deliver an environmental solution prior to a pre-defined deadline.



The implementation of the electronic diesel product was the first network project to be undertaken, both in terms of production networking and the assembly line modifications at the facility. A total of $14 million dollars was spent on assembly and test tooling alone, plus the costs involved in the design and development of the product itself. The main constraint within the project was set by the European environment and transport governing body, whose agenda it was to improve the emissions levels of diesel engine products – this is commonly known as the Euro III compliant emissions standard. If companies within the production network did not meet the legislation, then the opportunity to attract new customers as well as retaining the existing ones could have been in jeopardy. The consequences of not meeting this deadline would also mean severe financial penalties on all engines manufactured after the deadline date.

When analysing the projected volumes, it was apparent that the ISBe product would supersede non-electronic products over a period of approximately ten years. This was primarily due to the introduction of Euro III emissions and the necessity to produce cleaner emissions solutions and avoid heavy government taxes.

5.1 Engine Design Changes

There were many different design changes during the assembly line modifications. These included

- Rear gear train arrangement

All engine variants currently being built were a front gear train product. In order to assemble the front and rear gear train through the same process, modifications were required to the production lines. This came in the form of turntables, either in-between stations or actually on the station itself. The engine could then be orientated as and when required. This is a good example of the necessity for flexibility in mass customised assembly. This fundamental change would enable more flexibility for future new product releases due to the fact that both front and rear gear train products could be built.

- Cylinder block pan rail width increase

The characteristics of the cylinder block were also different to that of its mechanical predecessor. There was an increase in the oil pan rail width to enable increased oil capacity in the sump. This would have a large impact on the assembly process, as all of the engine transportation trolleys around the plant as modifications required modification. These modifications were to be designed so that existing product could still be assembled. This is another example of increased flexibility within the existing assembly process to incorporate variation of products.

- Increased crankshaft length

There were considerations to be made around the logistics of how to load the crankshaft into the cylinder block due to different lengths of cranks by product type.

A new crank loading machine was purchased that was capable of loading all crankshaft designs.

- Structural and non structural cylinder blocks

The introduction of new cylinder blocks presented issues similar to that of item 2 – cylinder block pan rail width increase. The necessity to transport cylinder blocks with physically different dimensions proved to be a challenge

- High pressure common rail system

A new high pressure common rail system was introduced requiring significant capital investment in order to ensure cylinder head assembly capability. Poke yoke was required for the fuel injector assembly to ensure that all injectors were tightened into the cylinder head. In addition to this, cylinder head high pressure line poke yoke was designed and installed to ensure capability on a safety critical joint.

- Four valve cylinder head

ISBe product was a four valve head design as opposed to the two valve mechanical product. Significant modifications were required to the cylinder head rundown machine, namely to the torque program and torque tool alignment processes.

- Full authority electronics

The ISBe engine required an ECM (engine control module) to control all electronic components on the engine. There was also a requirement to provide programming equipment for all engine variants so that the correct program could be added to the product type – dependant on customer requirements.

The existing assembly process was evaluated to understand the needs of the ISBe electronic engine assembly and highlighted where additional / modified machinery and equipment was required. With such a wide range of products being assembled throughout the same line, major emphasis was placed on protecting the quality of product and meeting the customer's requirements.

As a result, more poke yoke would be required, along with improved torque tooling and in-process verification.

5.2Strategy

(Process Amenability Pillar Two and Organisational Readiness Pillar Four)

The assembly strategy was to utilise as much of the existing Short block and Long Block assembly equipment as possible, by modifying existing machines and work stations where possible to accept all engine model types. The main items of equipment are listed below;

- All assembly pallets for the Long and Short block lines
- Semi automated crank loading to handle eight engine variants
- Automatic IPV machine to measure bump height, torque to turn and final torque of piston connecting rod bolts
- Semi automatic assembly of crankshaft front and rear cassette seals
- Automatic machine for run down of oil pan bolts
- Auto torque of rocker post bolts
- Automatic valve lash setting machine
- Anaerobic gasket spreading machines for front cover gear housing and gear cover.

The introduction of a more automated process would enable the current headcount to be reduced, therefore reducing the direct labour costs. Although the initial outlay of this equipment would be at a considerable cost, the long term benefits would be crucial, especially when considering the competitive environment (pillar three). This is different to the strategy described in the literature review where it was suggested that more manual processes can enable more flexibility during assembly. This is a point that will be discussed when developing the framework

5.3Impact of Technology on the Environment

When analysing the figures, the projected volumes were such that the ISBe product would supersede non-ISBe products over a period of approximately ten years. This was primarily due to the introduction of EURO III emissions legislation and the necessity to produce a cleaner product, so as to avoid heavy government taxes. In order to help Companies plan ahead with the introduction of emissions compliant products, the European Emissions Governing body have a pre-defined time line illustrating legislation change dates. It is up to the Companies within the manufacturing sector to deliver the viable technology solutions. This can have a fundamental impact on the way an organisation is run. Product change will impact the way a production line operates thus highlighting the importance of design for an existing environment. In this particular case all of the project deliverables were achieved i.e. the engine was Euro III emissions compliant and assembled through the existing process.

5.4Discussion

The implementation of ISBe product was the first network project undertaken by this particular company, both in terms of production networking and the assembly line modification. A total of $14 million dollars was spent on assembly and test tooling alone, not including the costs involved in the design and development of the product. The main constraint within the project was set by the European Environment and Transport governing body, whose agenda was to improve the emissions levels of modern day diesel engines – this is known as the EURO III emissions standard. If companies within the production network did not meet the legislation, then the opportunity to attract new customers as well as retaining the existing ones could have been in jeopardy. When analysing the strategies used in both the ASB and ISBe engine implementation it is clear to see that neither provided the definitive answer on how best to approach a mass customised new product introduction.

There was however some common approaches that was used to form each manufacturing strategy. These were to consider;

- Throughput capacities - impact on existing process, costs and labour
- Quality – Customer quality levels, internal quality levels
- Time to market – meeting legislation deadlines
- Delivery to the customer – fulfilling the customers demands
- Cost reduction – utilizing existing processes

The ten company operating practices were also considered as part of a corporate strategy. The practices are part of the corporate policy that are used to guide all business units within the organisation. The new product introduction process must consider these in order to develop a successful introduction. This is demonstrated in figure 5.1.

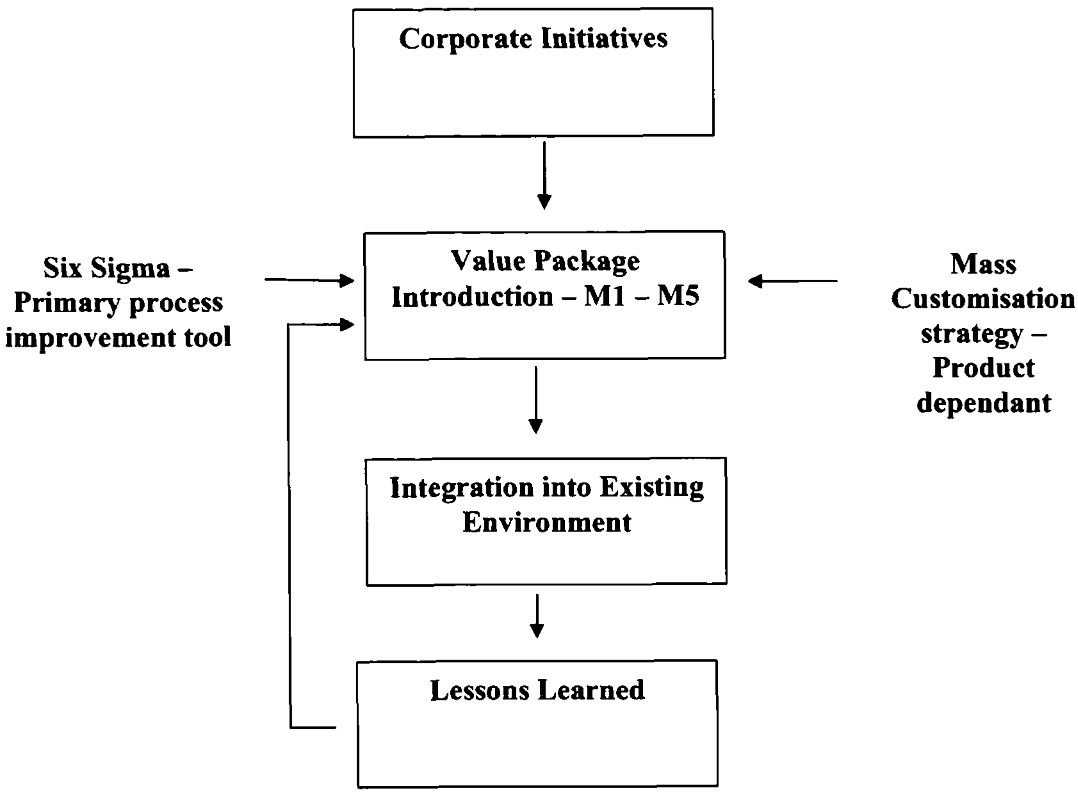


Figure 5.1 Process flow of value package introduction

Chapter 6 describes how to use these common approaches to develop a framework to be used for mass customised engine assembly.

Chapter Six: The Framework

6.0 Introduction

It is apparent from the two case studies that a Mass Customisation framework is specific to the product that is being introduced. However, there are some common areas that need to be considered during the development of the framework. These are as follows;

- The uniqueness of the customer needs, which is aligned to pillar one of the four pillars of Mass Customisation.
- Marketing, design, production and distribution that links directly to process amenability (pillar two).
- The competitive gain from the implementation of a mass customisation strategy (pillar 3)
- The organisational culture and resources of a company (pillar 4)

All of these areas were considered carefully within the company examined throughout the two case studies detailed in the previous chapters. Once the four pillars are fully understood and embraced by a company it can then start to develop a framework for Mass Customisation. A strategy can then be developed to include core areas of a business such as;

- Cost – the production strategy and logistical requirements
- Quality – the potential impact of Mass Customisation on Quality
- Delivery – the supply base and material flows
- Environment – external and internal environmental factors
- Design – how to integrate mass customised products into an existing environment
- Production – Adaptable production to cope with mix model schedule
- Marketing – better forecast on existing products and first to market with new

When observing the company operating strategy for the implementation of new products as documented in the previous chapter, there was strong evidence to suggest that key performance indicators could be linked directly to the four pillars of Mass Customisation. The diagram below has been created to illustrate linkage between key performance indicators and the four pillars.

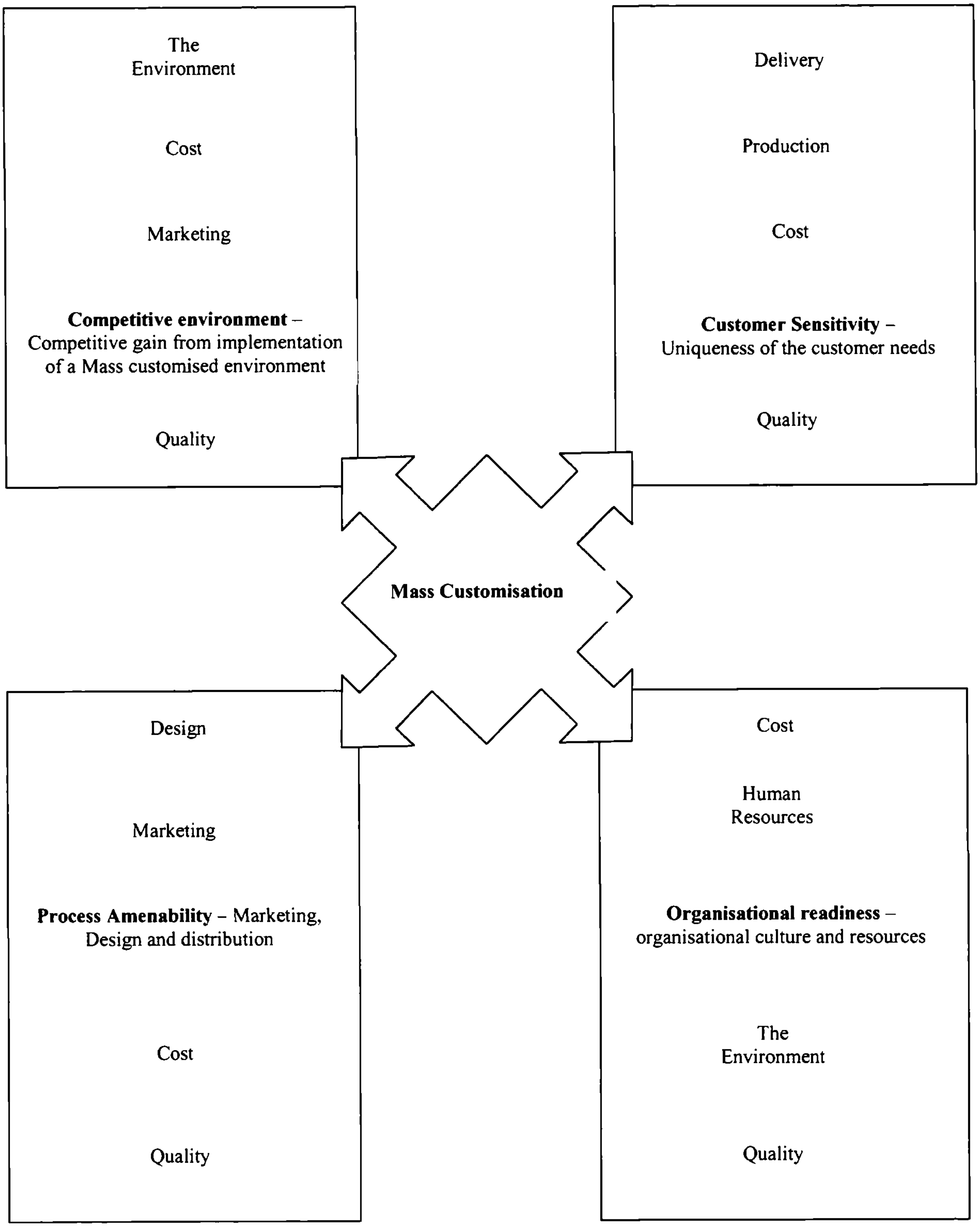


Figure 6.1 Competitive factors in Mass Customisation

6.1 Framework Development

It is difficult, if not impossible to develop a generic strategy for Mass Customisation to be used across a range of different organisations. The strategy needs to be specific to the environment and the product as Companies' employ different strategies to satisfy the needs of the business and customer.

In order to aid the development of a Mass Customisation framework it was possible to utilise the two case studies in chapter 5 as they were both taken from the same Company and shared the same new product introduction strategy. Both of the observed case studies followed a similar flow, both in terms of meeting common goals within predefined time frames. The significant differences between the two projects were the amount of Capital and resource required to achieve the deliverables.

In both examples, the lessons learned were used to identify improvements and to change processes and procedures in order to improve future new product introduction programmes. It was therefore important to use these common areas to form the basis of the mass customisation framework.

6.3 Mass Customisation Framework Development

In order to better understand the new product introduction strategy, it was necessary to map out the common milestones from each project as detailed in figure 6.2.

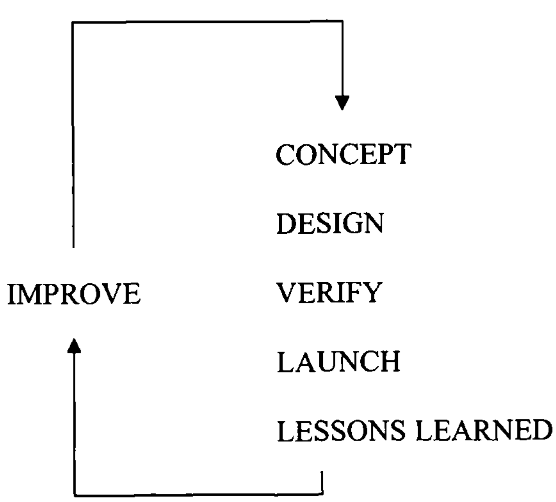


Figure 6.2 New product introduction milestones

The above milestones formed the part of a formal M review process as described in the research methodology chapter. These milestones were a proven strategy for the introduction of new products and it was therefore relevant to include these areas as part of the Mass Customisation strategy.

As discussed in the literature review, there must be a genuine need from within the company to employ a Mass Customisation strategy, so much so, that in large Organisation's it may need to be incorporated as part of the corporate strategy. For the purposes of this work and based upon the company studied, the corporate strategy will form part of the framework.

6.4 The Product and Environment

There are two main factors that need to be considered when generating a corporate strategy, these are, (i) the environment and (ii) the product. Each factor is critical to the functioning of a company and there are many overlaps and interactions between the two. A good example of this was detailed in the case study on the agricultural engine introduction, where the unique design of the product dictated a number of physical changes to the production environment, both in terms of the Plant layout and the process flow. A second example of where the environment can influence the product is the introduction of the electronic emissions compliant engine, detailed in case study 2. The external environmental influences directly impacted on the design and assembly of the product. Based upon the examples within the case study, the Product and Environment were added to the framework. The interactions are detailed in the chart below;

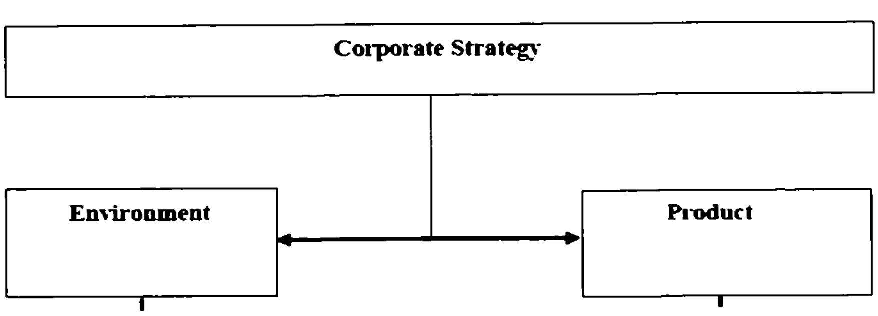


Figure 6.3 Product and Environment.

6.5 The Four Pillars

It was evident from both case studies that the four pillars were considered in great detail and have therefore have also been included as part of the framework. They supersede the Product and Environment, as it is important to establish first, whether a company's product dictates a mass customisation strategy and whether the physical environment is capable of undertaking such a magnitude of change.

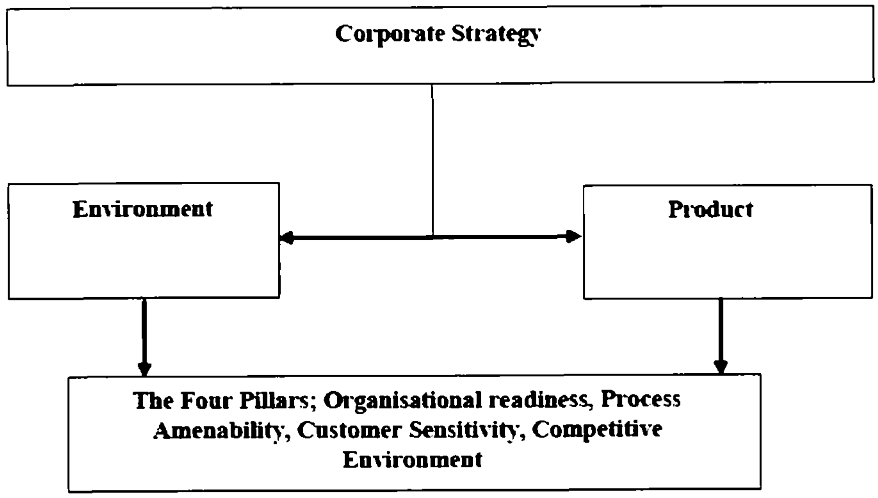


Figure 6.4 The Four Pillars

The above flow chart details where the four pillars fit into the flow of the corporate strategy.

6.6 Key Process Indicators

The key process indicators are the generic types of indicators that would be at the heart of the majority of manufacturing businesses and certainly relevant to the company observed within the case studies. These indicators have been linked directly into the four pillars of mass customisation. The reasoning behind this was to ensure that each indicator was considered when evaluating each of the four pillars. For example, when a company is considering process amenability (pillar 2) then they should also consider;

Cost - upgrades of existing machinery or the purchasing of new

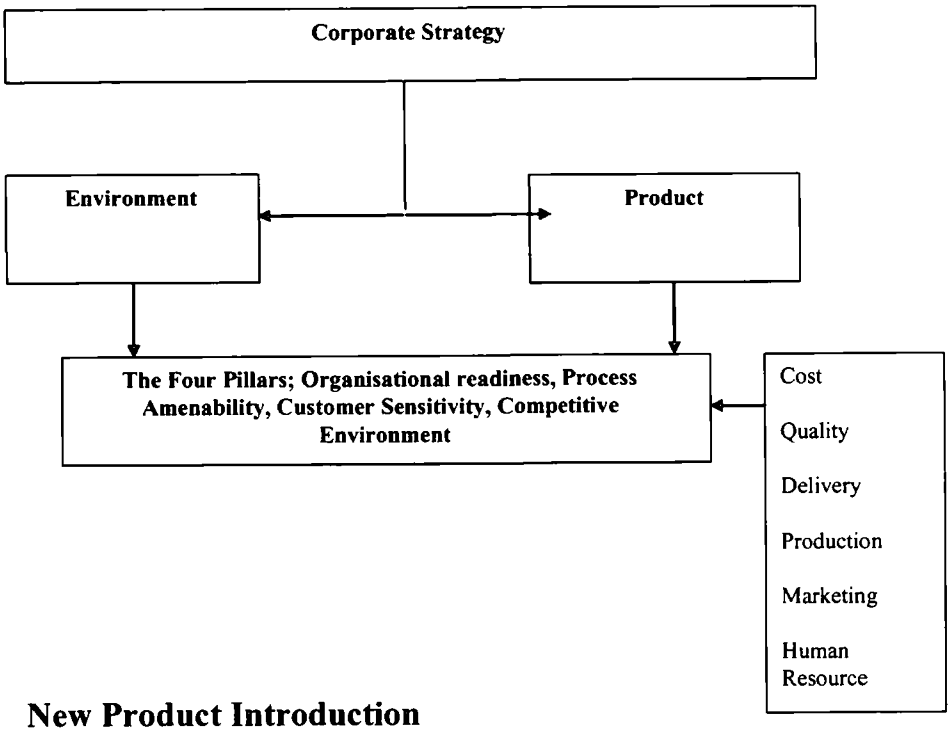
Quality - considerations when increasing assembly and product complexity

Delivery - dealing with the complexity of additional

Production - different production strategy to cope with product complexity

Marketing - the ability to tap into existing markets

HR - Headcount requirements for additional business



6.7 New Product Introduction

New product introduction is a key part of the framework as it runs hand in hand with mass customisation. As an Organisation moves away from a more traditional mass production strategy, so the number of new components / products increases. It is for this reason that new product introduction is added to the framework. An important point to note is now far down the framework new production introduction appears. This further emphasises the required level of work that is required before a new product can be introduced.

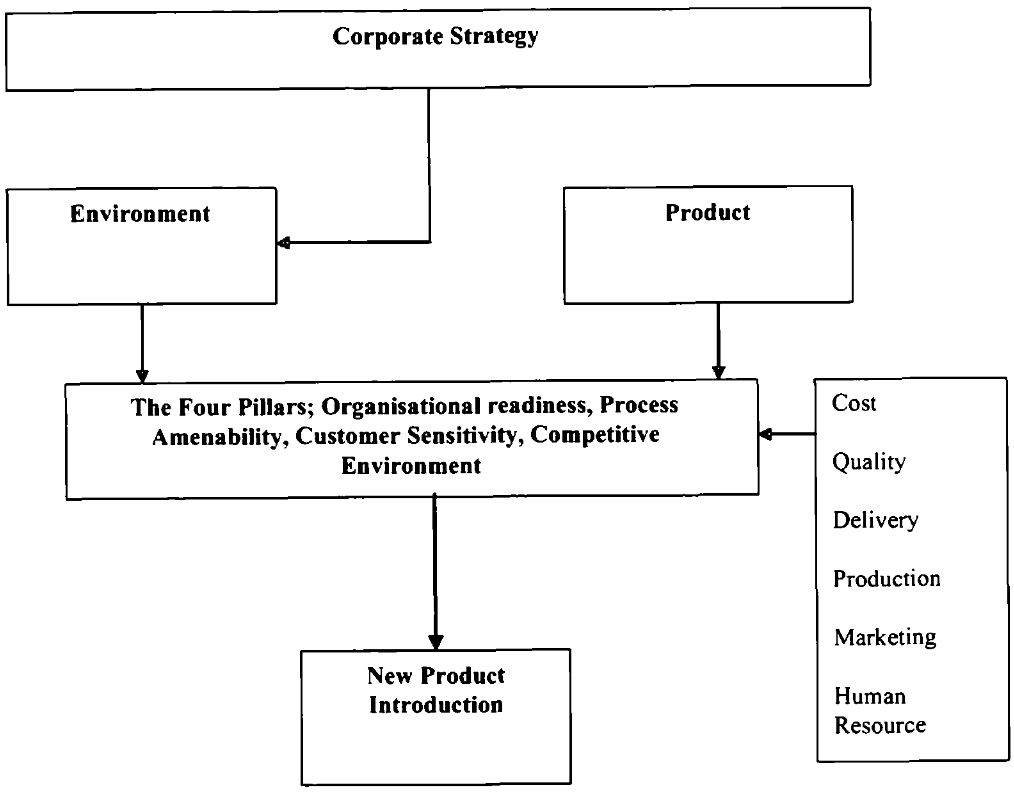


Figure 6.5 New Product Introduction

6.8 Continuous Improvement

An important part of any project or strategy introduction is to evaluate the effectiveness of the work undertaken and learn from any issues that were highlighted during the project. This was certainly evident in both of the case studies observed in chapter 5 and the results of which were formally documented for future new product introduction teams to consider. The success of generating the lessons learned was observed through the cross functional group discussions that took place upon the project completion. This ensured full participation from the full spectrum of departments and team members and allowed for the most constructive of sessions. For this reason it has been included as part of the framework is used to improve the elements of the framework at every level.

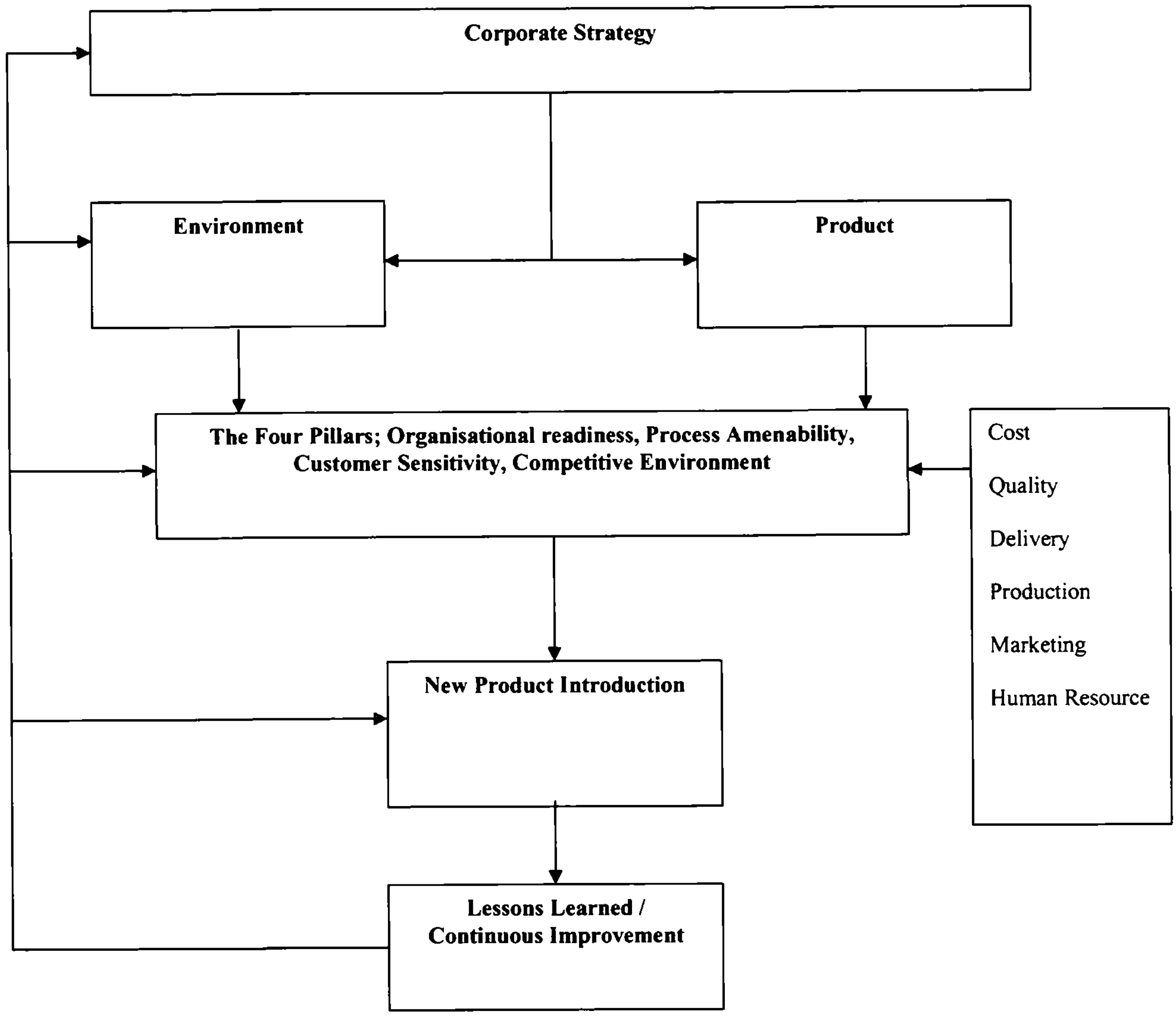


Figure 6.6 The Framework

Chapter Seven: Discussions and Conclusions

7.0. Discussion

As discussed in the abstract, the implementation of mass customisation is by no means an easy task to achieve. However, it has been possible to investigate the areas within manufacturing that need to be considered when implementing a mass customised strategy. The use of 'real life' case studies was crucial in order to compare current mass customisation practices to that of other companies in the literature review. From these comparisons could be drawn, along with differences.

It is of course difficult, if not impossible to copy a mass customisation strategy that has been implemented into an existing manufacturing environment. This is mainly because operating strategies are specific to the company and customer needs. Every organisation has a strategy that is very much a vision of how it, the company feels is the best way in which to direct the Corporation both in terms of improved operating strategy and increased market share. These are areas within the four pillars of mass customisation that are not particularly well defined. A good example of this is the 'environment'. There are many different factors that need to be considered. The two main areas are listed below;

(i) Physical environment – to ensure that the work environment is all above safe, clean, healthy and secure. The work environment gives employees and visitors a good impression and makes it easier to accomplish work.

(ii) Cultural environment – to ensure that as a company, overall business success depends on the ability to effectively communicate with employees. The company vision helps set the direction of the company. It is necessary to seek the diversity in ideas and experiences from employees regardless of racial / cultural backgrounds, age, gender or disability.

The case study highlighted in the literature review shows how the environment can have benefits of reducing operational costs within a company. Such areas can include the recycling of waste, reducing waste disposal costs and also generating a physical environment where people like to work. This can in-turn creates an increase in throughput and generates financial gains to the bottom line of the company.

7.1. Lean Manufacturing and the Impact on Mass Customisation.

Both new product introductions discussed within the case studies were undertaken in a lean manufacturing environment. As discussed in the first case study, the structural engine new product introduction, there was a requirement to ensure that the assembly strategy maximised the resources available and ensured an efficient and cost effective operation. One of the constraints of the project was the limited capital budget available to introduce the product. The main reason for this was that it was not cost effective to upgrade a production line at a cost of millions of dollars for low volume product. This was a good example of the issues that mass customisation strategies can have on new product introduction. The literature review suggested that adaptable production could be considered an appropriate strategy to design into the assembly process to counteract the increase in the proliferation of products. This would be a slight shift away from the current semi-automated production environment. The materials group were also heavily involved in the lean production strategy. The creation of synchronised material flow has been essential in increasing inventory turns. It was a pre-requisite that from the time the material is delivered, it should remain moving until it leaves the Plant In a customised environment, this can be increasingly difficult to achieve, due to the amount of different components required for each specification of engine. This can be addressed by improving the ability to forecast customer demand and therefore better plan the delivery of material into the Plant. The ISBe electronic engine implementation was at the other end of the spectrum in terms of size of product. There was a total of $14 million spent on assembly, test and tooling alone, not to mention the costs involved in design and the development of the product. To distribute the substantial cost, a production network team was set up. This has been referenced in many case studies as a way of achieving success through learning from each others knowledge in order to achieve the desired result. The ISBe product introduction was a good example where three companies combined in order to design and develop an engine capable of meeting the emissions legislation. This example shows how competitors can work together to achieve the desired outcome.

The cost constraints that were attached to the structural product did not allow for a complete assembly process upgrade, however, the ISBe electronic engine implementation did present an opportunity to increase the level of automation within the process. These included machines to perform critical operations such as;

- Torque to turn – measuring the torque required to turn the crankshaft

- Top dead centre setting – the timing of the camshaft gear to the fuel pump
- Crank end float – the end to end movement of the crank in the cylinder block.

These were operations that were traditionally high on assembly cycle time and quality critical to the assembly of the engine. Flexibility was built into all of these machines to ensure that all new types of engine models currently in the design phase were capable of being processed through the machines.

Although automation comes at a price, there are distinct advantages when implemented, but, how do we know this was the right decision to make in the two case studies? There are examples referenced in the literature review that suggested the use of adaptable production as a strategy for mass customisation. This is where more manual processes are used to address more complex assemblies.

7.2. Summary

The VPI process was developed as a strategy for the implementation of new products within the company. This process was used in both the ISBe and structural new product introductions. The above projects have been successful in addressing critical areas within each project. These are as follows;

- Volumes
- Financials
- Technical
- Operations
- Purchasing
- Aftermarket
- Marketing

The VPI planning process aims to look at the product beyond the point of sale to the customer and includes the after-sales section as part of the product introduction. The process encourages the involvement of cross functional teams in the implementation of new products. This was identified in the literature review as a beneficial strategy for a company to undertake in order to be successful. One of the main reasons for this is the ability to use a vast array of knowledge from the team and address critical areas such as design for assembly and process capability. In both case studies this has proven to be successful and has helped the new product assembly to be capable throughout the process. One area that was not observed on both case studies was the group location of the cross-functional team. It was suggested in the literature review was that grouping of team members can encourage information flow and reduce product implementation times from concept to production. This is a recommendation that was made to the company as it could be very useful in a customised environment.

There are many different areas within manufacturing that need to be flexible in order to be competitive in a mass customised environment. There have been many different examples in the case studies where processes have been changed in order to meet customer requirements. What is of most importance when considering mass customisation is that the procedures are specific to the range of products that are being produced and the assembly and manufacturing process involved. DFA has a major part to play in mass customisation to enable products to be built throughout the process which will in turn reduce costs in capital outlay and labour overheads.

In summary, mass customisation can have a large impact in the way new products are implemented into a company. It is not an easy task to achieve and there are no set guidelines in the way it can be achieved. It is key to understand the needs of the customer and also the work required to change the existing environment.

Manufacturing is an extremely competitive sector and there are many different strategies that can be undertaken in order to meet the needs of both the product and the environment. One of the suggestions is for further work is to benchmark different companies whom undertake a mass customisation strategy in order to further gain an understanding of the unique strategies that are practiced, along with reasons for doing so. The opportunity to use the case studies within the thesis has highlighted important areas to consider, especially when introducing new products into an existing environment.

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