THE NEW MANUFACTURING

Executive Summary

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Declaration

I declare that the contents of the portfolio incorporating the different projects is either solely my work or work in which I have made some contribution as a project team member. My share of the total work content of the project teams is discussed in this Executive Summary and also at the beginning of each report. Those new methodologies and research findings presented in the portfolio which have been published (or accepted for publication) or presented in conferences are also indicated accordingly.

Summary

The world of manufacturing organisations has changed considerably in the past few years which give rise to three research areas which constitute the context of what I have called The New Manufacturing

1. What is the current state of affairs in the trading relationships between partners in the supply chains and what would be a best practice model for such relationships?
2. What is the impact on the strategy process of the changes in the trading relationships and focus on cross-functional and cross-organisational business processes?
3. How do you integrate the new competitive factors of speed and flexibility with the need for agility and re-invention and implementation of world class lean manufacturing practices?

The portfolio is divided into three distinct parts. The first part develops the 'external context' of manufacturing organisations by analysing the trends in trading relationships between supply chain partners through a EU funded research project on European automotive industry. The second part explores the link between the 'internal' and the 'external' context by developing the concept of 're-positioning' as a new dimension to existing strategy development approaches. The third part explores the 'internal context' and seeks new solutions to issues in strategy formulation and manufacturing systems design, using 'time' and 'turbulence' as key change drivers along with the traditional 'focus' approach.

The analysis of the 'external context' uses a cohesive 'best practice' model incorporating 11 characteristics as the fixed point comparator for analysing 24 supply chains in 6 car assemblers. The findings show significant changes in both the 'structural' and 'relationship management' characteristics such as greater outsourcing and systems purchase, single sourcing at part number level, greater design and development delegation by the vehicle manufacturers, open book costing, leaner manufacturing pipeline and long term contracts. A key finding is the emergence of 'multi-customer' suppliers - suppliers with close, non-adversarial relationships with a number of key customers. This multi-customer structural feature was investigated using four theoretical trading structures in a detailed case study of an automotive supplier and was found to reflect characteristics of all four.

The changes in the supply chains underlined the need for a 're-positioning' methodology for suppliers hoping to change their 'value boundary', in addition to existing strategy formulation methods, which did not address this specific requirement. Thus the second part of the portfolio proposes a new 're-positioning' methodology, which represents the link between the external and the internal context, which was then validated through a study of a supplier who had 're-positioned' and through application in two SMEs.

The 'internal context' analysis represents the major part of the portfolio, and was carried out at two companies using approaches and techniques new to the companies. In one of them, a new process focused strategy formulation was used to develop strategic goals for the two key processes. In the same company, a complete manufacturing analysis was carried out using 'time' as the strategic driver, as part of an overall 'systems' approach, which was a major change for the company. As a result, a number of changes were proposed of which some have been implemented and a key success has been the reduction of manufacturing lead time from over 6 weeks to 3 weeks or less with corresponding reduction in inventory. At the other company, the project scope was limited to improving performance of machining cells. Again using 'time' as a key driver of change as part of a 'systems' approach, a number of new practices were introduced which led to improvement in lead times, inventory and service levels for pilot components. A key innovation in both companies was the development of the concept of 'turbulence' to analyse manufacturing issues which was then integrated with the well known 'focus' approach and the more recent 'time compression' into a generic multi-dimensional approach to the design of manufacturing systems.

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THE NEW MANUFACTURING

1.0 Introduction

The world of manufacturing organisations has changed considerably in the past few years and is still changing. In one view this change will itself become the 'constant', with organisations structuring themselves to operate in such a fluid environment. On the other hand, the current process of rapid change may be transient and could converge into a more stable environment. Observers have catalogued numerous reasons for this change : shorter product life cycles, greater customising to suit individual customers, accelerating change in process technologies, more stringent environmental regulations, and globalisation of markets being a few of them. (Ohmae 1990, Slack 1991, McCutcheon et al 1994). Charles Handy (1990) declared that we inhabit an 'age of unreason' where certainty and predictability are a casualty.

The impact of these environmental changes is nothing if not cataclysmic on organisations. New forms of organisational structures are sprouting, and de-control, de-layering, empowerment, subsidiarity, and learning organisations are some of the buzz terms being coined to reflect these developments. Business processes are forming the building block of organisations and core competencies are driving the competitive postures. As Tom Peters (1990) said dramatically, 'get innovative or get dead'.

1.1 The Environment for Manufacturing Organisations

The success of Japanese firms in grabbing significant share of the western markets beginning in the 1970s forced a fundamental review of how the organisations in the west did business with each other. From this review emerged the concept of supply chain management and the notion of partnerships with suppliers in the inbound logistics side and distributors, retailers and dealers in the outbound logistics side. Coupled with these are the changes in the trading practices discussed in Section 1.4.1 of this report.

A consequence of the increased competition is the focus on the final customer and the need to maximise the value offered. It is realised that to achieve this imperative, it is not sufficient to improve only one's own performance but the performance of all the so-called partners in the supply chain. Thus developed the concept of extended enterprise (Ernest 1993). In this view of organisations, proprietary boundaries are less significant than the key value adding processes which cut across not only functions within each organisation but across the organisational boundaries.

The changes in the competitive factors are no less significant. Cost, quality, reliability were no longer the order winning criteria (Hill 1985) in many market segments. Speed - time to market (concept to design), time to volume (design to delivery) and time to customer (material in-process time) - and flexibility have become the key to greater market share and profitability or even survival. (Stalk and Hout 1990, Hill and Chambers 1991).

Another dimension to competitive requirements is the instability and unpredictability of these requirements. It is not sufficient to design a manufacturing system to meet specified customer requirements, the traditional top-down approach. The instability and unpredictability of inputs into the manufacturing system causes 'turbulence' (Bhattacharya et al 1995a) leading to loss of performance. It is thus equally important to make the manufacturing system 'agile' (Goldman and Nagel 1993) and 're-inventable' (Jina et al 1995) to minimise turbulence which is more akin to a bottom-up approach.

Another lesson learned by the west from the successful Japanese firms are the so-called World Class practices of 'lean manufacturing' - Just-in-time, multi-skilling and teamwork, statistical process control and process capability, kaizen or continuous improvement, cellular manufacturing and flow-lines and total productive maintenance (Schonberger 1986, Suzaki 1987, Womack et al 1990).

Arising from all these changes in the environment for manufacturing organisations are several critical questions and issues

1. What is the current state of affairs in the trading relationships between partners in the supply chains and what would be a best practice model for such relationships?

2. What is the impact on the strategy process of the changes in the trading relationships and focus on cross-functional and cross-organisational business processes?
3. How do you integrate the new competitive factors of speed and flexibility with the need for agility and re-invention and implementation of the world class lean manufacturing practices?

It is these key issues that the portfolio addresses and a brief overview of each area will be described in this summary, but first a word on the structure of the portfolio and methodology.

1.2 Structure of and Contribution to the Portfolio

When a manufacturing organisation is analysed in context of the three key issues listed earlier, it can be seen that the context can be divided into three parts : the *external* context, the *external-internal* link and the *internal* context. Thus the portfolio is divided into these three parts, and using a combination of research findings, case studies and actual implementation it presents an integrated and innovative approach for improving the performance of any manufacturing organisation.

In each of the projects that make up this portfolio, I have worked as part of project teams with different level of individual contributions. When constructing the portfolio, a key question arose of what to include as my work, and as it is impossible to delineate outputs which are specific to me or otherwise, I have decided to present the entire output for each of the projects. However to explain my contribution, each report, except the Executive Summary has an introductory section which presents the context of the report and a section titled 'My Contribution and Innovation'. The latter attempts to clarify my contribution to the projects and the innovation that I brought into them.

Coming back to the three parts of the portfolio, the first part develops the **'external context'** (in relation to a specific manufacturing firm) through the analysis of the trends in the trading relationships between partners in supply chains. This is done in two stages; the first stage presents some of the findings of a research project on supply chains in the European Automotive industry called the Future Working Structures (FWS) project which was funded

by the European Union[1]. The second stage presents a case study of a 'multi-customer' supplier firm which represents the confluence of practices of the various trading structural alternatives. While the FWS research and the multi-customer case study represents roughly 20% of the total work content of the portfolio, my own share of the FWS project work was only about 10%. In contrast, the multi-customer case study, which was a follow-up research, was mostly done by me.

The second part of the portfolio represents the link between the **'external'** and the **'internal'** context. The changes in the external context, namely in the trading relationships, had underlined the need for another dimension to the conventional strategic process for those suppliers who wished to increase the 'added-value' or re-draw their value boundary. In this part of the portfolio, a 're-positioning' methodology is postulated which can be adopted by firms lower down in the supply chains. This new methodology is validated through data collection on a supplier who has re-positioned and then through application in two SME case studies. This part of the portfolio represents roughly 10% of the total work content and was mostly done by me.

The third and final part deals with the **'internal context'** of a manufacturing organisation and discusses the need to change the functionally oriented strategy formulation to a process orientated approach and presents two detailed case studies on re-design of manufacturing systems; one involving the entire organisation and the other restricted to the component machining area. The case studies bring out the need to adopt a multi-step methodology for designing a manufacturing system, presented later in the report, which incorporates the traditional top-down 'focus' analysis, the need for speed of process and 'turbulence' minimisation. The work in these two case companies represent the remaining 70% of the total work content. As for my own contribution as part of the project teams, one case company (Company D) represents approximately 80% and the other (Company E) about 40%.

The portfolio is structured into 12 Reports including the Executive Summary which are listed in Table 1. Six of these reports discuss the findings of the FWS research project and case studies, and the remaining five are submissions of papers, of which four have been published,

[1] The FWS project report is now available from the European Union.

accepted for publication or presented at conferences. These papers present new approaches and methodologies which have been used in the various projects in the case companies or are the result of learning points from these projects. The portfolio is also supported by the submission of two papers (listed in Appendix A) which complement and support the portfolio.

Table 1. List of Submissions to the Engineering Doctorate Portfolio

The New Manufacturing

Report 1. Executive Summary

A. Trading Relationship : A Framework for New Manufacturing

Report 2 : Trends in the Trading Relationships in the European Automotive Industry
Report 3 : A Case Study of a Multi-Customer Automotive Supplier

B. Re-positioning in the Supply Chain : A New Dimension to Strategy

Report 4 : Re-positioning the Supplier : An SME Perspective (subsequently published)
Report 5 : Case 1 : Re-positioning an SME : Company B
Report 6 : Case 2 : Re-positioning an SME : Company C
Report 7 : Re-engineering the Supply Chain : A Supplier's Perspective [2] (subsequently published)

C. Implementing New Manufacturing

Report 8 : A Holistic Approach to Management of Change
Report 9 : Strategy Formulation : Focusing on Core Competencies and Processes (subsequently published)
Report 10 : A New Perspective in Manufacturing Systems Design : Turbulence Management and Rapid Re-Invention (based on two conference papers)
Report 11 : Company D : Manufacturing Strategy Formulation and Implementation. This report is divided into five parts
- 11 (a) Preliminary analysis and project formulation
- 11 (b) Manufacturing strategy formulation
- 11 (c) Detailed Analysis and Recommendations
- 11 (d) Teamwork, Reward and recognition system
- 11 (e) Implementation

Report 12 : Company E. : Improving Performance of Cellular Manufacturing. This report is divided into a three parts
- 12 (a) Preliminary analysis and project formulation
- 12 (b) Detailed Analysis of Performance of Cellular Manufacturing
- 12 (c) Implementation

[2] Details of re-positioning by Company A is presented in this report.

1.3 Research Methods and their Rationale

In constructing the portfolio different research methods were used befitting the specific requirements of the different parts of the portfolio. The objective of the first part of the portfolio was to understand the trends in the supply chains in the European automotive industry and to develop a 'best practice' model of trading relationships. The research project had two stages; the first was a study of some twenty four supply chains belonging to six vehicle manufacturers (VM) and the second was a detailed and focused study of a key supplier to most of these VMs.

For the 'external context' or first stage of the project, an empirical approach was initially adopted to develop a best practice model based on observations of 24 investigated supply chains. However comparison between the supply chains was found to be extremely difficult and the methodology was modified to develop a 'best practice' model of supply chains as the fixed point comparator, based on a literature review, previous experience of the research team and initial data collection and then through observation of the supply chains to validate and/or modify this model. The instrument used was a structured interview questionnaire supported by discussion at meetings with respondents who had been classified as buyer, designer or logistics person at the vehicle manufacturer and supplier.

The research project had raised certain key questions about the structure of the supply chains in the context of the differences between Japanese and traditional western practices (Bhattacharya et al 1996a) and the emergence of what can be termed as 'multi-customer' (the term is explained in Section 1.4.2 of this report) supplier relationships in the European automotive industry. This was sought to be examined through a detailed study of one such 'multi-customer' supplier. The research method involved postulating the four theoretical supply chain structures based on a literature review in order to give a label to the emerging structure, and then studying some of the key trading practices involving this supplier using a structured questionnaire. The respondents from the chosen case company belonged to product management, logistics and manufacturing functions from their two main plants in the UK and Germany. The findings from each of the investigated trading practices were then compared

against the four theoretical models in order to characterise the emerging structure for this typical multi-customer supplier.

As will be discussed in a later section, the changes in the supply chains underlined the need for a new approach which would help all those suppliers intending to 're-position' themselves in the supply chain through re-distribution of the added-value between trading partners. In the second part of the portfolio which can be seen as the link between the 'internal' and the 'external' context, the research methodology of postulating a new approach and then validating it through data collection and/or application was followed. A new methodology of supplier 're-positioning' was developed which was then validated by studying the re-positioning of an automotive supplier (Company A) and application in two SMEs (Company B and C) which involved the owners in a strategy development process.

The third and final part of the portfolio focuses on the 'internal context' of manufacturing organisations and represents the major share of the total effort in developing the portfolio. The focus of the work in this part of the portfolio was the development of manufacturing strategy and system in one case company and the improvement of cellular manufacturing performance in another.

In the first company, a new approach to strategy formulation which focused on business processes was postulated and then applied to develop strategic goals for the two key processes. The next stage of manufacturing system design followed the typical 'systems' methodology of preliminary analysis, data gathering, detailed analysis, synthesis, implementation and review supported by a new tool developed by WMG called the Time Based Process Mapping (TBPM)[3].

In the second case company the same systems approach was followed which was augmented by the application of appropriate tools and techniques like Time Based Process Mapping, Pareto analysis, and Production Flow Analysis (PFA). World class lean manufacturing

[3] A TBPM is a visual method to plot a process using time as the scale. There are two key differences between TBPM and other time mapping techniques like Gantt charts. First, the focus is on the due date, so the map starts off from the end point and goes backward through the process. Secondly, inventory is represented in terms of days production and so immediate comparison can be drawn between necessary inventory levels due to lead times and existing levels. a note on TBPM is presented as Appendix 2 in Report 12.

practices like JIT/kanban, cellular manufacturing/teamwork, flow lines and supporting layout, and integrated performance measures were incorporated as appropriate into the implementation process. (These terms have been explained and referenced in the main body of the portfolio as appropriate).

In both these companies, project teams were set up to work in conjunction with Warwick Manufacturing Group in order to develop the skills within the firms and also to keep the ownership of the problems within the companies. The four different research methods adopted in developing this portfolio are summarised in Table 2.

Table 2. Summary of the Research Methods Used in the Portfolio

Part of the Portfolio	Basic Approach	Validation Process	Key Outputs
Part 1 ***The External Context*** Trends in European automotive supply chains	Best practice model based on literature review	Data gathering on 24 supply chains belonging to 6 European car assemblers using structured questionnaires	Trends in trading practices in European automotive industry in comparison to the best practice model
Multi-customer supplier case study	Four theoretical models of trading structures and their characteristics constructed from literature review	Using a structured questionnaire to gather data, compare the current trading practices with the characteristics of each model	Emerging structure in relationship to theoretical models
Part 2 ***External-internal Context*** Re-positioning - a new dimension in strategy process	Develop re-positioning methodology as part of the strategy process	Validate through application in two SMEs Validate through data gathered from a re-positioned supplier	Re-positioning methodology
Part 3 ***Internal Context*** Implementing New Manufacturing	1. A process based approach to strategy formulation 2. Systems approach to manufacturing systems design, using tools like TBPM, Pareto, PFA, and incorporating lean manufacturing practices like JIT/kanban, teamwork/cellular manufacturing and flow lines.	Validate the process approach through application to one company	A new framework for strategy formulation process and design of manufacturing systems supported by a 're-invention' process.

Having established a brief overview of the whole portfolio, the remainder of this Executive Summary will focus on the summary of the work carried out.

1.4 Part 1 - Developing the External Context

1.4.1 Trends in Trading Relationships in the European Automotive Industry

In recent years the management of supply chains has gripped the imagination of both academic researchers and practitioners alike as a key factor in gaining competitive advantage (Lamming 1993, Ellram 1992). Supply chain management is an approach whereby the entire process of translating the customer requirements into completed products starting from the basic raw material to finished goods is treated as the basis of analysis and optimisation. This calls for close relationships or 'partnerships' between the trading members of supply chains as opposed to traditional adversarial relationships practiced in the west (Macbeth and Ferguson 1994, Dyer and Ouchi 1993).

The automotive industry in Europe has been a fragmented one with a large number of manufacturers, some large and a host of medium sized ones. Competition has always been intense but specially so with the recent advent of Japanese transplants. At the same time development of such approaches and management practices like lean manufacturing, business process re-engineering, supply chain management, teamwork and empowerment, have been revolutionizing how organisations are structured and managed. These developments triggered the need to study the competitiveness of the European automotive industry and led the European Union to set up the Future Working Structures (FWS) research project which comprised of four Tasks of which one was researching the supply chains. The findings are presented in this portfolio in Report 2 and a summary is presented below.

Three key issues facing the European Automotive industry were identified, which were :

- *Over Capacity* in the world automotive industry and thus the need to reduce costs to stay competitive
- Demand for *Quick Response* and thus the need to improve speed to market and speed to manufacture
- Demand for *Variety* and thus the need to manage variety in an environment of increasing technological complexity of the product

These three issues and the lessons learnt from the success of the Japanese manufacturers (Womack et al 1990) have been forcing the western automotive firms to re-think their management of supply chains and ask the question : what is the best practice? Various researchers have come up with their own answer and have used different names to categorise such trading relationships : lean supply (Lamming 1993), extended enterprise (Ernest 1993), virtual enterprise (Johansson et al 1993), value adding partnerships (Johnston and Lawrence 1988).

The key question before the project team was : what characteristics constitute a coherent framework for evaluation and measurement of supply chains in context of the three key issues? Eleven such characteristics, shown in Table 3, were identified and developed into a coherent model of theoretical 'best practice' - a fixed point of reference or comparator (alternatively called phantom benchmarks, Brace et al 1994 and presented in Paper 1 - see Appendix A) against which the supply chains under study were compared. [4]

The next stage of the research project was to gather data from 24 supply chains belonging to six participating vehicle manufacturers (VMs) : BMW, Mercedes Benz, PSA, Renault, Rover and Ford of Europe for the four designated components/systems : Electronic Control Unit (ECU), Wiring Harness, Door Process Chain and Instrument Panel.

Table 3. Supply Chain Characteristics

[4] The methodology adopted for investigating the supply chains using these 11 characteristics gives a qualitative assessment of the gap - the position of actual practice relative to the fixed model. Subsequently a quantitative way to measure the 'gap' and represent the current position of a specific supply chain vis-à-vis the theoretical model on a 'radar' graph was developed but has not been reported in this portfolio due to reasons mentioned in Report 2.

Characteristics	*Definition of best practice*
Structure	
Tiered Supply Base	Clear demarcation of roles between trading partners for optimal resource allocation with the first tier carrying out a development/systems integration role. Inter-dependence between the supplier and customer resulting in higher stability of relationship. Control of lower tier suppliers by one tier above. Horizontal collaboration between suppliers in the 1st tier.
Higher Outsourcing	Increase level of design/development and assembly outsourcing if it reduces cost.
Systems Purchasing	Total service supply - purchase the logical 'end-point' system to reduce complexity and cost, through outsourcing both assembly and design/development
Relationship	
Single Sourcing	Per model range or part number.
Design & Development Delegation	'Seamless' product design/development either through collaborative projects or full delegation with joint control.
Long-term Contracts	Model-life contracts.
Customer Focus	Customer dedicated manufacturing and design/development teams and assets on part of the supplier.
Open-book Costing	Cost transparency and compatibility of accounting systems.
Mutual Development	Sharing of long term information to allow joint planning, joint mutual assessment and joint teams for solving problems.
Open Systems	Computer supported collaborative work using integrated broadband communications, including EDI and CAD.
JIT Manufacture and Deliveries	'True' lean pipeline through in-sequence JIT manufacture and delivery : needs schedule stability, variety reduction, standardised re-usable containers, logistics partner, local manufacture.

1.4.1.1 Summary of the Supply Chain Research Findings

The research findings on each of the eleven characteristics are discussed below.

Tiering

The transition to a tiered structure in Europe seems to be more evolutionary in nature than planned, but trends were confusing. Results show an unfocused, non-dedicated supply base with many suppliers capable of both direct and indirect supply from the same plant/business, and both low and high levels of integration. For example, suppliers provide systems for some customers whilst still supplying discrete components for others. Choice of second level suppliers and control of the relationship with second level was often found to be retained by the VM. Only 4-5 supply chains had a degree of tiering.

Outsourcing

While there are differences in the level of outsourcing between VMs, they are beginning to experiment with increased levels of integration of outsourced parts and all except one had higher than minimum level of outsourcing, with 6 having a significantly high level of outsourcing.

Systems purchasing

The study revealed an increasing trend towards systems purchasing with each new model introduction (Coleman et al 1995a) and half the supply chains supplied some form of a system of all four investigated components.

Single sourcing

The study revealed a distinct trend towards reducing the number of suppliers in a move towards single sourcing and the most common sourcing policy appeared to be single source by part number with 20 out of 24 supply chains doing so.

Design and development delegation

Nearly all the supply chains investigated had delegated design fully or partially. 'Black box' or fully delegated design/development was done in 5 supply chains, high share of the design by the VM in 4 supply chains and the rest were 'gray-box' design/development except 1 where the VM did the entire design. However desire was expressed by some suppliers of the need to be involved at an earlier stage in the design and development process before the specifications of the surrounding parts were finalised.

Long-term contracts

Four of the six VMs representing 14 supply chains went into model-life contracts with their suppliers, and the other two had annually renewed contracts. However, even for these two, it was indicated that unless something went drastically wrong, the chosen supplier would supply over the model life. All model life contracts, however, have a clause for price negotiation after every 12 months depending on the volumes, cost reduction targets and an opt-out clause for both partners.

Customer focus

20 out of 24 supply chains had focused their manufacturing assets on the customer. One extreme of manufacturing focus was co-located plants and the other extreme was where suppliers use 'Chinese Walls' to internally demarcate customer specific assets. However the efficacy of such internal demarcation to maintain confidentiality is sometimes questioned (Bhattacharya et al 1996a). Design/development was less customer focused with 5 of the supply chains so structured. The highest was for one supplier who had a permanent customer focused design team with compatible CAD system.

Open-book costing (OBC)

All VMs insist on cost data from the suppliers particularly in the case of key systems and also use the data to drive cost reduction programmes. However some suppliers view the request for full cost information as intrusive and areas like one-off capital investments and overheads can lead to time consuming discussion to reach agreement. For suppliers with many customers with different costing systems, it is an added burden to operate different OBC systems.

Mutual Development

Joint planning and transparency of information does not occur though some model volume information may be passed by the VM to the supplier. While all the VMs use a supplier audit to evaluate the supplier's business, the supplier has no structured process to evaluate his customer's business in relation to him. The common approach is to identify the problem at the supplier end, provide some education and training to the supplier if necessary, and let the supplier attempt to solve it. Thus 'mutual development' through joint problem solving of such perennial problems like schedule instability does not take place.

Open Systems

With all supply chains using EDI for commercial information transfer and CAD for design information transfer, a move towards Open Systems is clearly indicated. However, the information transfer is still one-sided, from the VM to the supplier, and with lack of common standards and broad band-width communication still in its infancy, true Open Systems is still some way off.

JIT deliveries

All the supply chains, with one exception where the last operation was JIT, had so called 'apparent' JIT, i.e. only JIT delivery from finished goods stocks, and consequently, true 'lean supply' which involves JIT manufacture and delivery throughout the supply chain is still far off. The major cause appears to be schedule instability, with fluctuations both either in total volume or mix requirements, and late variation between actual and forecast delivery. Most of the VMs profess a move towards a greater proportion of part numbers delivered in sequence Just-In-Time for final assembly.

1.4.1.2 Some Conclusions

The research findings revealed that all 6 VMs are moving towards the best practice model though there were clear 'gaps' between the best and current practice. Some of the key conclusions that can be drawn from the study are

- The best practice model comprising the eleven characteristics provides a holistic approach to evaluating and measuring the supply chains, similar to frameworks proposed by researchers like Lamming (1993) but different from most literature on supply chains which focus on only one or several of these characteristics. The use of this broader approach for studying European automotive supply chains represents a major achievement.
- There were differences between the closeness to the best practice among VMs and also within the eleven characteristics.
- A key finding was the emergence of a 'multi-customer' supply chain structure which is a cross between the traditional western model and the Japanese model, and with some additional features, and so represents either a new structure or a structure under transition.[5]
- While the VMs and large powerful supplier companies describe the trading relationships as "Partnership", the smaller suppliers still view the developments with some skepticism.
- With a greater level of outsourcing design delegation, fragmentation of the knowledge base for car manufacture appears to be happening but is inadequately recognised.

[5] This feature is discussed in greater detail in the next section through a detailed study of such a multi-customer supplier.

- With the same customer supplying similar systems to all its customers, VMs have to balance the risk of losing product differentiation against the benefit of economies of scale enjoyed by such suppliers.
- While the suppliers had moved towards customer focused organisational structures, VMs still had at least four functions that dealt, often independently and with conflicting objectives, with the supplier : buyer, designer, logistics and the line managers.

If we go back to the three key issues of over capacity, quick response and variety management and the supply chain performance measures that flow from these issues, it can be seen that each of the eleven characteristics contribute to meeting these performance measures as summarised below.

Over capacity in the world automotive industry is making cost reduction an urgent priority. VMs are adopting global sourcing as a cost reduction and single sourcing to remove redundancy. JIT reduces costs. Open book costing is a monitoring and cost reduction tool. Over capacity in the market also increases the risks of VMs. Higher outsourcing helps to share risks among trading partners and their shareholders.

Quick response is demanded by the consumer. While JIT addresses the time to manufacture, design and development delegation (and hence concurrent engineering) address the time to market. Open systems enable it to happen through quickened and uninterrupted information flows.

Demand for increased variety, particularly when coupled to quick response, gives rise to ever increasing complexity. The need to reduce complexity is being addressed through a higher level of outsourcing, the development of large specialised suppliers and the trend towards systems sourcing. This leads to increased fragmentation of the knowledge base. Longer term contracts, mutual development and open systems are all measures to counter the fragmentation and to foster 'partnerships'. Renewed vertical integration is unlikely precisely because it increases complexity.

1.4.2 Case Study of a Multi-Customer Automotive Supplier

One of the key findings of the FWS study was the emergence of a 'multi-customer' supplier structure in the European automotive industry. The term 'multi-customer' is used in a specific manner. It is not to say that suppliers did not always have several customers in Europe. Of course they did. But they often did not have any strong linkage to their customers. The trading relationship was purely contractual and short-term. On the other hand, the term multi-customer refers to long term non-adversarial relationship between a supplier and its customers who have categorised that supplier in their preferred supplier list making up their rationalised supplier base. This multi-customer structure appeared to be a cross between the traditional western and the Japanese keiretsu supply chains, with some additional features.

Thus, it was found necessary to study one supplier in greater depth to understand the nature of such multi-customer supplier trading relationships. Specifically

- how was an order placed on such suppliers,
- what decided the level of integration and added-value supplied,
- did collaboration between suppliers contributing to the same system take place and if yes who initiated it,

as the drivers that create different structural configurations.[6] Thus the first step was to develop the four theoretical trading models and their characteristics with respect to the three structural drivers. These four trading models have been discussed in detail in Report 3 and summarised in Table 4 as the basis of analysing the emerging multi-customer practices. There were found to be four model differentiating features :

- How partnerships were formed?
- What was the extent of ownership and stability of value distribution among the partners?
- How stable were the relationships?
- How dedicated were the relationships?

[6] The three structural characteristics of best practice model - tiering,, higher outsourcing and systems purchase - are subsumed within these structural questions and represent a specific answer to these questions.

Table 4. The Four Trading Structures

Trading Structure	Advantages	Disadvantages
Traditional western • *Stable distribution of value among trading firms* • *Less value outsourced* • *Adversarial, short-term* • *Price competition among suppliers* • *Each customer with many supplier and vice versa*	1. Competition between suppliers leads to 'creative tension' and can result in product and process innovation and lowest price	1. Higher co-ordination costs of managing a more complex supply chain. 2. High risks posed by low control over the suppliers. 3. Higher requirement of capital by the product owner
Japanese • *Stable distribution of value among trading partners* • *More value outsourced* • *Partnership, often equity cross-holding* • *Long term , Target costing* • *Keiretsu - dedicated supplier base*	1. Low risk through control of suppliers part of (quasi vertical integrated) keiretsus 2. Access to more capital through the suppliers 3. Common customer focused goal 4. Higher stability for suppliers and so more efficient operations	1. Low 'creative tension' between suppliers. 2. With one customer, suppliers had lower economies of scale of researching new product and process technologies.
Extended enterprise • *Same as Japanese except no customer dedication - multi-customer suppliers*	1. Benefits of multi-customer relationships in terms of scope to develop new product and process technologies and learn from different customers.	1. The partnership was still unequal, the supplier was usually a 'follower'. 2. There was always a possibility that a supplier not part of the preferred supplier list may develop new technologies which the product owner may be slow to get access to.
Virtual enterprise • *Partnership to exploit market niches, bringing together 'plug-compatible competencies, short term or model-life specific* • *Value distribution unstable and designed to best suit particular market niche or model*	1. Access to new technologies 2. Rapid access to markets 3. Concentrate on and exploit core competencies	1. A highly evolved, change oriented organisational culture required 2. Clash of organisational cultures as organisations may not know each other

1.4.2.1 Summary of the Research Findings

Discussion with the selected multi-customer supplier company revealed the following trends (the research findings are discussed in more detail in Report 3).

- Temporary model specific alliances or more longer term market niche specific alliances are emerging between suppliers contributing to supply of complex systems. These alliances are

not driven by the product owner but result from proactive re-positioning by the suppliers themselves.

- The lead partner among these emerging model specific alliances may change from one model to another or from one product owner specific supply chain to another, even though the same suppliers are partners. This feature is characteristic of the virtual enterprise model (Goldman et al 1995).
- For each new model competitive tendering or 'concept competition' takes place between the preferred suppliers for each commodity group of a VM, a practice similar to price competition of the traditional western model. The selection is however not solely based on price but seeks the best possible price-technical solution fit and the process is far more co-operative. Thus the selected supplier/partner for each new model may be different for a VM. This latter feature is again a characteristics of the virtual enterprise model.
- The level of system integration and value distribution between trading partners for each new model may vary, and seems to be decided on a case by case basis by the VMs. Proactive trading partners influence the distribution of value through presentations of different options for supply of systems with varying levels of integration.
- Despite non-stable relationships across models, universally understood trading practices or 'rules of the game', which may not be mentioned specifically in any contract, bind the trading partners together. On the other hand, contractual codes are not iron bound and a trading partner may, if justified, break them with the agreement of the other partner.
- Consolidation is creating large multi-customer suppliers who have similar negotiating power as the large VMs. Thus there is far more equality in the trading relationships which is a feature of the extended enterprise or the virtual enterprise model as opposed to the VM dominated Japanese model.
- Proactive suppliers have started to collaborate horizontally and pool their core competencies in order to offer 'systems' capability for specific new model development programmes. This collaboration is not initiated by the VM in many cases.
- Other Japanese or extended enterprise model practices like target costing. close co-operation and mutual development, higher outsourced value and JIT supply were part of the trading relationships involving the case company.

1.4.2.2 The Structure Conundrum

The findings clearly suggest that characteristics of all four supply chain models are present in the trading relationships involving the case company. As the selected automotive supplier is seen as typical of most progressive European automotive suppliers, one may want to extend the conclusions to the European automotive industry as a whole. However, more research is needed to confirm this assumption.

There could be two rationales behind the findings. One could argue that the diffusion curve for all the four models have overlapped and that is why features of all four models are present. In this view, taking a temporal picture of the emergence of each model, one would suggest that over period of time, the model of virtual enterprise would be adopted more widely.

The other rationale could be that these four models are not mutually exclusive and in practice only a hybrid which adopts the characteristics from each model to best suit the industry or the particular supply chain would be adopted. That could explains the presence of features from all four models in the case study.

Which of these two views is correct? Conclusions from one case study are not sufficient evidence to answer this question. Personally I feel that both views have strong cases. However, the most recently developed trading model of a virtual enterprise may be more appropriate in some industries which exploit short term market requirements or where volumes are small and development costs are high while in more mature markets a hybrid model would be better suited. However more research is required in this area to answer some of the questions raised by this case study.

1.4.2.3 Additional Comments on Multi-Customer Suppliers

In addition to the structural issues, there were some additional findings from the investigation of the multi-customer supplier which supported some of the general findings of the FWS project.

This multi-customer structure is advantageous in situations where market volumes are low in relation to technology development costs, or in situations where the manufacturing process is particularly capital intensive. The customers also benefit from the learning achieved by a supplier working for several customers on the same technology.

On the other hand there are issues of confidentiality and product uniqueness. How does the supplier prevent information about one customer getting to another? Customer focused teams (discussed earlier) is one of the ways suppliers have adopted to deal with the issue of confidentiality. Some VMs feel that product uniqueness or ability to differentiate would be lost if suppliers supply the same or similar systems to all its customers. In response the VMs are identifying core or differentiating systems which they would like to keep in-house. Another route could be that proposed by Venkatesan (1992) who suggested that even if a company out-sourced some of its core systems, as long at it kept what he called the product 'architectural knowledge' inside the company, it would retain control over its 'differentiating capability'.

To conclude, published literature on developments in supply chains has concentrated on successful implementation of the Japanese model or its variation, the Extended Enterprise model by the western companies. The Virtual Enterprise model is still very much in the development stage. Consequently, the identification of the emerging multi-customer structure incorporating characteristics from all the four theoretical models represents an advance in our understanding of trading relationships.

1.5 Part 2 - Developing the External-Internal Link

1.5.1 Repositioning in the Supply Chain - A Missing Strategic Link

The history of strategy formulation in organisations show that there have been distinct stages, each heralding specific approaches and/or the 'structuredness' of the process itself. For example, in the 1970s and 1980s, strategic planning was seen as the panacea of all problems. Organisations like General Electric with their large strategic planning staff and their use of

structured planning techniques like the GE-McKinsey Grid (Wheelen and Hunger 1986) were seen as the model to be emulated.

All these approaches were based on the analysis of the growth and profitability of various product-market segments and followed an approach first popularised by Ansoff's Strategic Grid nearly 30 years ago (Ansoff 1968). Ansoff's approach calls for the selection of one of the four quadrants in the grid, i.e. develop new products or markets, grow or consolidate or sell-out in current markets or diversify into unrelated areas. In a similar fashion, the BCG (Boston Consulting Group) Matrix (Wheelen and Hunger 1986) was designed to suggest the attractiveness of current or potential product-market segments. Once the product-market segments were selected, a firm could adopt one of Porter's generic strategies (Porter 1980) to suit the competitive requirements.

The focus of all these approaches was on the end product-market. The firm selected those market segments it wanted to compete in and developed products and strategies to do so. This can be called the 'external to internal' approach, i.e. analyse the external environment first in terms of markets, and develop the internal organisation to suit the needs of those markets that the firm finds attractive. This was the period of the big conglomerations and the highly vertically integrated firms.

The late 1980s and early 1990s introduced a fundamentally new strategic approach with the presentation of the concept of core competencies by Prahalad and Hamel (1990). They and other researchers (like Boynton and Victor 1991, Quinn and Paquette 1990, Kay 1993) postulated that the 'external to internal' approaches had got it wrong. Rather than focus on the market first, firms should be identifying their core competencies which are very much technology or process based and then seek to find the markets where these competencies could be leveraged for competitive advantage. Thus the focus was very much 'internal to external'.

Even before this new thinking on core competency based strategy emerged, other researchers on the strategy process (Quinn et al 1988, Mintzberg and Waters 1985) started suggesting that increasing complexity of the external environment which firms sought to counter by increasingly complex process of top-down strategic planning using complex forecasting systems was an 'oxymoron', since it was impossible to forecast when the pace of change was

so rapid. They suggested that rather than have such complex top-down strategic planning, firms should develop strategic thinking capabilities at all levels in organisations so that bottom-up strategic change could emerge when there was a need for it.

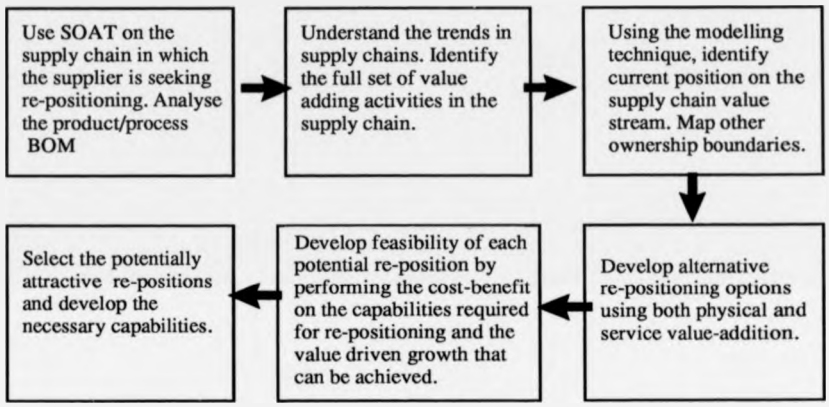
The twin approaches of core competencies and strategic thinking/emergent strategies appear complementary. The word 'core' is the link. The very nature of these competencies means that they reside in the depth of the organisations, within the value adding processes. Those who operate these processes are the people who probably know how to best exploit them. If they are imbibed with strategic thinking and allowed to deal with the external environment, they would take decisions which in Mintzberg's terms would be 'emergent'.

But there is one missing link in all this. In an earlier section we discussed the trends in the supply chains and the emerging pattern of value stream distribution clearly suggested that the value map was unstable and more and more value was contributed by the suppliers. The concept of core competencies and other traditional strategic approaches fail to consider the opportunities provided by these supply chain trends. The failure is one key area. These strategic and marketing approaches seek to find new products or markets (discounting 'harvesting' strategies), which can be termed the horizontal or new customer route to growth. These new markets are sought using the existing core competencies.

However, the trends towards 'system' purchase and single sourcing mean that for suppliers of industrial products who are lower down the supply chain, the growth that can be achieved through adopting the horizontal or the new customer route is limited precisely because new customers are not available. In fact customers are disappearing as supplier bases are rationalised. Secondly, customers want the suppliers to supply higher added value which require additional competencies. Consequently, competencies have to be considered as dynamic and not static.

Therefore, in addition to the usual strategic approaches, these trends in the supply chains call for a new 're-positioning' dimension - the missing link, which can lead to a 'vertical' or 'value' route to growth. Such an approach was developed and follows the six steps summarised in Figure 1. This approach is presented in detail in Reports 4 and 7. In it, the supplier does not seek new supply chains to become a member of but instead seeks to increase his contribution

to the value stream of his existing supply chains. The supplier, thus, needs to analyse the supply chain 'looking up' the product structure, seeking parts of the value stream which the customer wishes to relinquish, and bringing them under his own proprietary boundary. This analysis is supply chain focused and looks 'up' the supply chain from a supplier's perspective rather than 'down' the supply chain from the product owner's perspective.



Key
SOAT : Supplier Opportunity Analysis Technique
BOM : Bill of Material

Figure 1. Steps in the Re-positioning Methodology

The first two steps in this methodology are to gather data on the value-addition activities in the supply chain using a structured questionnaire based on this philosophy called Supplier Opportunity Analysis Technique (SOAT) (Bhattacharya et al 1995b) and a framework for qualitative analysis which seeks to plot the supplier's position on a two dimensional matrix of Value Addition - Differentiation (or physical value - service value)[7]. The next two steps are to model current position by superimposing the value ownership boundaries on the value-adding activities in the supply chain, and develop potential re-positioning options of value ownership boundaries (Coleman et al 1995b). The next step is to understand the capabilities needed and carry out a cost-benefit analysis for each of the re-positioning options. The final step is to select the re-positioning option and develop the required capabilities.

There are two key differences between SOAT and the modeling technique and other market analysis techniques. The first difference is that while SOAT's focus is narrow in the sense that it is limited to a specific supply chain or customer, the scope of traditional market analysis is broad as it covers all current and potential customers. The second difference is that in its product strategy, SOAT's scope is broad in that it goes beyond the structure of the currently supplied product and seeks opportunity resting within the customer's product assembly. Traditional market analysis usually restricts itself to the existing product and its enhancements[8].

Those suppliers who proactively build the additional capabilities to supply increased added-value obviously have a greater chance of being successful. Such suppliers actively seek to 're-position' themselves in their existing supply chains as part of their strategic process. How does the supplier act proactively? Traditionally, the supplier did not have access nor did he seek to have access to the customer's engineering Bill of Material (BOM), which could tell him how his product was used by the customer. He was told to supply a part or a sub-assembly or carry out a process and he would do just that. However, if he analysed the engineering BOM, he would know which parts or sub-assemblies were added to the bits that he supplied to make up a functional system. He would need to ascertain if it made economic sense for the customer to source out the entire system or sub-system. If yes, then the supplier had to decide which bits of the value stream that made up this system or sub-system could be brought in-house to add to his core value stream. These additional capabilities could comprise of combination of design, assembly, test, supplier management, etc.

The dynamic nature of competencies needed to adopt a re-positioning strategy can be understood by visualising a product as comprising a core value stream and an expandable value stream, the latter being specific to each customer, product or model. Thus a supplier might supply one customer product based on his core competency and another customer a product that uses both the core competency and additional capabilities. As discussed before, such

[7] This part of the re-positioning methodology is presented in Report 4 and Paper 2.

[8] One of the growth strategies which can be adopted is the 'penetration' strategy which seeks to increase growth from current customers. However, the difference between the penetration and re-positiong strategy is that penetration seeks to increase volume through increased usage through new applications or more frequent usage of the same product unlike re-positioning which can change the product substantially.

changing added-value contribution from the supplier is a characteristic of the virtual enterprise and could become a more common feature in future supply chains.

1.5.2 Case Studies in Re-positioning

The methodology of supplier re-positioning was developed through observation of suppliers making such a transition as part of the FWS study, one of which is reported as Company A in the case studies that follow. The methodology was then validated further through application in two SMEs presented as case studies B and C below and submitted as Reports 5 and 6 in the portfolio.

1.5.2.1 Company A, a supplier of pressed parts for door-process systems to the auto industry could foresee the changes in his supply chain. It started to develop design capabilities and enhanced the 'value' of its products by undertaking the design work. In the next stage it analysed the engineering BOM of the door system to understand the various value addition stages which its parts went through. It started to build the capabilities which would enable it to undertake the assembly of the complete door module. The company was soon supplying door modules with various levels of integration to some customers, effectively re-positioning its business from lower down the supply chain into a system integrator for some supply chains.

Even though this company did not use SOAT and the modeling technique directly, its strategic approach to proactively build its capability and re-position its business provides the best validation of a need for a structured methodology like SOAT and its modelling technique.

1.5.2.2 Company B, a small prototype panel supplier to the auto industry, supplying primarily small and medium panels and brackets, on using SOAT realised that its customers were moving to the concept of prime contractor (1st tier-supplier) who would provide the services of model making, tool making and prototype metal working as a package. A key capability for such a supplier, if it were to supply the more complex and high value panels (skin and structural panels) would be the use of CAD/CAM. However, this capability was not a prerequisite for other panels and brackets which constituted the majority in terms of numbers. The company felt that the risk involved through investment in CAD/CAM, even though it

would increase the value offered to the customers, was too much. At the same time it did not want to lose out on the benefits of becoming a prime contractor managing the rest of the supply chain (model and tool maker). The company would like to adopt a strategy of forming an alliance with a model and tool maker so that it could offer a higher value to its customers without taking on the risk of investing in additional capabilities, effectively re-positioning his business.

This company, as most other companies would do, sought to increase its sales by seeking out new customers. In an automotive industry where customers were shedding suppliers, getting new business was not very easy. Using a methodology like SOAT was innovative in that the company saw the potential of exploring the 'value' route to growth from its existing customer base.

1.5.2.3 Company C, a small company anodising aluminum parts for a wide variety of industry, which could be broadly classified as food and non-food, also found that its customers were moving to the concept of prime contractor (1st tier supplier) and outsourcing greater value. However, since this SME was seen as a specialist process provider, a process that added 'cost' in the view of most of its customers, the company found it difficult to take advantage of the changes in the supply chain in the non-food industry sectors. On the other hand, in the supply chains in the food sector, anodising was a high value added process and this company was a key player and found it profitable to explore re-positioning options. It identified products where it could add simple assembly capabilities as part of its value stream and started negotiating with his customers to enable it to re-position for these specific products.

This company, because of the specialist nature of its business is, perhaps, not the best example for application of SOAT as it added a very low share to the total value of a product in the non-food sector. However, the philosophy of SOAT made the company explore the potential of increasing the value of its products. Since increase in 'physical' value was difficult in the non-food sector as explained earlier, it ended up implementing a new customer servicing system which increased the 'service' value of its products and had the potential of increasing its profits. On the other hand, in the food sector, SOAT's re-positioning philosophy was applicable and as a result the company is exploring options to increase its added-value with its existing customer base.

1.5.3 Some Conclusions on Re-positioning Methodology

The case studies revealed that one of the key requirements for successful application of this technique is to get sufficient information on the Bill of Material for the product assembly which requires close co-operation with the customer. This must be coupled with an understanding of the capabilities needed for re-positioning and the cost of acquiring these capabilities. Anecdotal evidence presented in Paper 2 (see Appendix A) suggests that a supplier who is proactive in doing so has the best chance of increasing the value it offers and thus re-positioning itself.

The constraint of this methodology vis-à-vis other market analysis techniques is that while the latter are applicable in all marketing situations, the re-positioning methodology can be used only by suppliers who are at least one step upstream from the final manufacturer in the supply chain and who provide one of the several key capabilities needed to put together a sub-system or a system of a complex product. A supplier like Company C which is not a key supplier will find it difficult to re-position in the sense described in this report.

1.6 Part 3 - Developing the Internal Context

1.6.1 Implementing The New Manufacturing

The previous discussion highlighted two critical issues for the New Manufacturing Organisation. The first one was the form of trading structures between organisations and the role played by core competencies. The second one was the need to develop another dimension to the traditional strategic planning process, namely that of re-positioning in the supply chain. Both these issues are externally focused and deal with the strategic posture of a business that best meets the environment. In this section, we look at the internal organisation of a firm from two angles : the question of the relationship between strategy and structure and the design of the manufacturing system itself.

1.6.1.1 The Question of Strategy and Structure

The traditional process of strategy formulation in organisations has followed a hierarchical process, very much decreed by the functional structure of organisations. The central proposition of strategy formulation in the 1960s and 1970s was the alignment between strategy and structure, with the latter following the former which was the driver. (Chandler 1962, Galbraith and Nathanson 1978) But as Mintzberg (1994) observed recently, the functional organisational structures constrained the strategy process itself, and paradoxically, strategy rather than being the determinant of the structure and the organisational systems, became constrained in order to meet the needs of the functional structures. That is why most text books on strategy would have a hierarchical process depicted by Figure 2.

The functional organisational structure evolved from the need to develop specialisation and economies of scale within the organisational boundaries. They thus created 'locally' efficient organisations. That structure was fine as long as the external environment was stable. The inefficiencies of functional structure were well hidden.

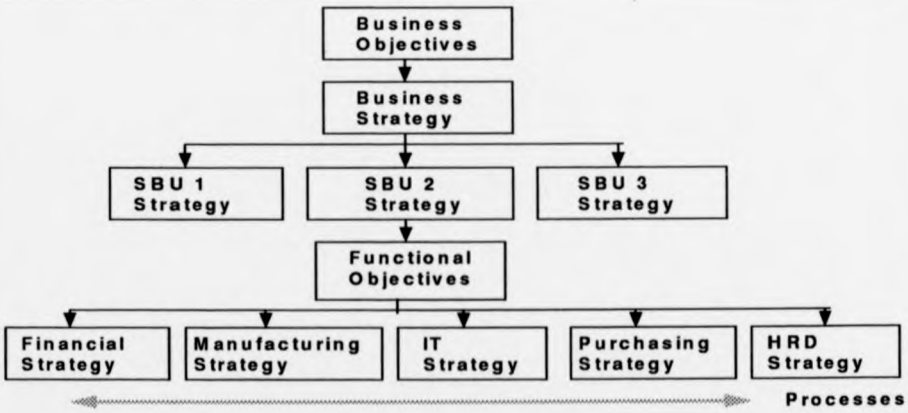


Figure 2. Hierarchical, Functional Strategy Formulation

The 1980s and 1990s brought more instability in the external environment with respect to both products and processes/technologies. The key competitive dimension moved from price/quality/product differentiation to customisation and time. (Stalk 1988, Stalk and Hout

1990, McCutcheon et al 1994, Gilmore 1993). Time to Market which covers the activities from concept to design, Time to Volume which covers the activities from design to first delivery and Time to Customer which covers the material in-process time were seen as key competitive areas[9].

The problem with these new strategic issues was two-fold. Firstly, they represented value-adding processes which cut across functions and thus required cross-functional working. Secondly, the 'hand-offs' between functions needed in order to carry out these processes increased lead times to levels which made the firms uncompetitive. For example, one of the case companies - Company D[10] - had a Time to Market of 36 weeks, operating in an industry which was becoming fashion oriented. Its Time to Customer was 6 weeks whereas the customer wanted response based on Electronic Point of Sales (EPOS) information. Clearly, the firm was becoming uncompetitive.

As explained these long lead times are partly explained by the hand-offs (transfer between one function and another) and the beauracracy created by functional structures. In Report 9 the problems with the traditional approach to the strategy-structure conundrum has been discussed in depth, in light of the various approaches currently being propounded in the business management literature. For example, in the last few years radical change in the organisational working has been proposed through approaches like Business Process Re-engineering (BPR) (Hammer 1990, Johansson et al 1993). These approaches recognise that 'value' is created in processes and not by functions and so organisations should be structured to facilitate smooth working of these value creating processes. The consequence is the radical restructuring illustrated in numerous case studies on the subject (Hammer and Champy 1993).

However, there are two key failures of the new approach. First, most applications seem to have attempted to use the approach to break the status quo and reduce 'local' costs without a link to business strategy, an assertion supported by the study carried out by Hall et al (1993) which showed that most BPR projects have either too little depth or too little breadth or both,

[9] The three terms - Time to Market, Time to Volume and Time to Customer - were defined and used as part of the methodology developed by the Time Compression Project team at WMG.

[10] Company D is one of the case companies presented in this section of the report. The manufacturing systems re-design project in this company is presented in Report 11 and involved carrying out a detailed analysis of the manufacturing process and recommending a series of proposals for the complete re-design of the process.

and only those companies that possessed the vision of both depth and breadth of restructuring were successful. The second failure is the lack of a link to the concept of core competencies, which is increasingly seen as the basis of strategic decisions and the emergence of new trading structures.

However, it is not too difficult to overcome both these failures. Fortunately, the way Prahalad and Hamel (1990) and others have defined core competencies suggests that these reside in processes and are the result of cross-functional working. So, the first step in the strategic process is to identify the required core competencies and those processes that support them. The next step is then to develop strategies for these processes in place of the traditional functional strategies. Such a process would turn the traditional strategic process on its side as shown in Figure3. This process oriented strategy formulation, focusing on core competencies is discussed in greater depth in Report 9.

Figure 3. Process Driven Strategy Formulation

Company D adopted this process oriented approach. At a strategic workshop the 'desired' core competencies were identified as designing wide variety of innovative products and getting them to the customer quickly, and secondly, responding swiftly to EPOS. This contrasted sharply with their current strength which was to produce good quality products, over a narrow range, cheaply and in large volumes. Two key processes were identified - New Product

Introduction and Garment Make process. Lead time objectives were set for both processes. A cross-functional project team then set about developing the template for change. Major structural and operational change recommendations were made, some of which have been put in place while others are being reviewed. These and some of the time compression activities at this company are also discussed in a later section.

The foregoing argument builds a case for process oriented strategy formulation as opposed to a functional one. The need for such a re-orientation comes not only from taking an internal view of organisations but also from the need to integrate each trading partner into a seamless supply chain. The value stream that creates a product can be viewed as a series of generic business processes like product creation, product supply, technology acquisition and logistics management. Parts of each of these generic processes are owned by different trading partners. Thus the only real link between these trading partners are the business processes and the information flow from one part of the process owned by one trading partner to another owned by another trading partner.

Taking this view of the value stream means that the logical way to develop business strategies is to take a process view, particularly in light of shift of value from one trading partner to another, an emerging feature of the European Automotive supply chains as discussed earlier in the report.

1.6.1.2 Design of Manufacturing Systems

In recent years there has been a lot of debate on the merits of following a top-down strategic planning approach versus a bottom-up approach, briefly touched upon in an earlier section. On the one hand, writers like Mintzberg (1994) argue the demise of top-down strategic planning whilst the other side of the argument has been carried by long time proponents like Ansoff (1988) who contend that the role of strategic planning is very much alive, the only factors to have changed are to do with the way it is formulated and applied.

This debate not only affects the strategic planning process but also the approach to manufacturing system design which has traditionally followed the top-down approach. The generally accepted principle is to determine the product-market requirements and then design

the manufacturing systems to meet these requirements. Thus there are two strategic concepts embedded in this approach. The first is the concept of focus and the second is that of alignment.

With the development of mass markets after World War II, 'economies of scale' played a major role in the design of manufacturing systems. At the same time the 'scope' of the manufacturing system was also expanded to include more product-markets and consequently more processes. Skinner who first developed the concept of focus in his seminal articles (1969, 1974) found that a manufacturing system can meet only a limited set of market driven objectives. He thus called for manufacturing to be focused to meet these narrowly defined market needs and called for limiting the 'scope'. Subsequently, Hayes and Wheelwright (1984) pointed out the diseconomies of scale and proposed the concept of factories within factories. Hill (1985, 1989) took the concept of focus a major step forward with his structured approach to manufacturing system design, developing the concepts of Order Winners and Order Qualifiers to link market requirements to manufacturing system design variables. In all these approaches, the principle was that once the narrow market driven needs were defined, the manufacturing system would be designed to be aligned with these needs. In addition, with the recognition that there would be variability in the inputs into the manufacturing system, a degree of 'first-order' (the meaning of the term is explained later) flexibility is required and this is built-in. However, the concept of flexibility is often not clearly understood and the wrong kind of flexibility is frequently chosen (Upton 1995, Hill and Chambers 1991).

1.6.1.2.1 The Concept of 'Turbulence' and the Need for a New Approach to Manufacturing System Design

The typical strategic time frame is usually 3-5 years within which the competitive priorities and manufacturing system design are expected to be largely unchanged. If there arises any misalignment between the competitive priorities and system design as inevitably it would, progressive organisations have a Continuous Improvement (Deming 1986) programme to correct them.

Whenever there is a misalignment between the manufacturing system design and the inputs entering the system, it gives rise to what can be termed as 'turbulence' in the manufacturing

pipeline, which if unchecked dissipates manufacturing performance. The term turbulence has been used to describe the disturbances in the smooth flow of material and information within the manufacturing process and its effect can be monitored and measured. Turbulence can arise from numerous causes, some external to the system like volume or mix or schedule changes or internal to the system like design or process changes. The typical approach has been to identify the impact of such changes right at the outset and build in the desired level of flexibility in the system design. For example, a manufacturing system may be designed to take care of a certain level of mix turbulence through flexibility measures like multi-skilling or flexible manufacturing systems.

A key innovation in this portfolio is the proposal that turbulence identification and measurement can be used as a bottom-up approach to signal the need for limited and local re-design of the manufacturing system, as opposed to the traditional top-down market/competitive priorities driven design of the entire manufacturing pipeline. (This approach is described in greater detail with examples from the two case companies in Report 10).

Having established the role turbulence can play, let us briefly examine why there may be a need to adopt such an approach in conjunction with the more traditional market based focus approach.

Often, the concept of focus when applied to the entire manufacturing system, while appealing at the conceptual level is difficult and expensive to implement, particularly in brown-field sites, as it may be uneconomical to create factories within factories or division of assets may not be practical. Secondly, this concept establishes a uniform set of rules across the entire pipeline, or in other words, the entire manufacturing pipeline has the same and equal capacity to manage turbulence. If the type and degree of turbulence varies across the pipeline, as it is most likely to, then adopting a uniform focus approach may not be appropriate.

This reasoning becomes very relevant in the context of cellular manufacturing, which is seen as a manufacturing best practice and is being increasingly adopted, though often not very successfully (Ingersoll Engineers 1991). Cellular manufacturing breaks up the manufacturing pipeline within well defined boundaries and thus provides both a context and a framework to

study the type and extent of turbulence at different points or cells in the manufacturing pipeline.

The other reason why the traditional approach is often not sufficient is the fact that the variability and uncertainty of inputs into the manufacturing system have increased quite considerably in the past few years. The difference between the two terms is the level of predictability - variability is more predictable than uncertainty. This makes it very difficult to judge what is the right type and level of flexibility that should be built into the design of the manufacturing system. Such difficulty raises two important points. First, the flexible system should itself be flexible enough to be changed. This can be seen as the 'second order' flexibility as opposed to the 'first order', which is the normal understanding and usage of the term. Second, there must be a way to indicate to the systems designer or to the operator that the manufacturing system needs to be 're-invented' (Jina et al 1995)[11] to build into it second order flexibility. Often manufacturing engineers fail to pick up signals for cell re-design as the competitive priorities have not changed in a substantive manner and dissipation of performance is seen a management issue rather than a systems design issue.

This makes the concept of turbulence the key to short-term, local or cell level, manufacturing systems re-design or re-invention, within the strategic time-frame. Using the same principle as statistical process control, turbulence monitors with tolerance limits can be used to trigger the re-invention. These monitors can be either cell based and specific to the turbulence affecting the cell or monitor intra-cell turbulence.

The final thread in the logic to show that a new and multi-dimensional approach to manufacturing systems design is desirable is provided by the need to meet the increasingly key competitive requirement of 'time' through increasing speed of process and thus time compression should be one of the key features of manufacturing systems design.

1.6.1.2.2 The New Approach to Manufacturing System Design

[11] The concept of re-invention is very similar to that of 'agile' manufacturing organisations as described by Goldman and Nagel (1993) who view agility as a prerequisite for virtual enterprise. However, while the concept of agility has been defined as the organisational capability to respond very quickly to changes in the market, the concept of re-invention is its prosaic application to manufacturing system design at the local or cell level.

The multi-step approach described below developed from the experience and learning from the projects in the two case companies and brings together the different threads of the aforementioned arguments. In this new approach, the meaning of the term 'focus' is broadened in connection with manufacturing systems design through linking it to turbulence.

As mentioned earlier the traditional use of the term 'focus' was in connection with narrowly defined product-market characteristics. However, since then, as the philosophy of 'focus' has been widely accepted as a key feature of manufacturing strategy, the basis of focus has also widened to include any of a number of criteria : product, process, market, volume and geography (Lee 1995). The concept of focus and turbulence can be brought together by looking at a manufacturing system design having two levels of focus

- the first level would look for the traditional 'global' focus based on product-market analysis[12].
- the second level of 'focus' would operate at cell or team level and would use the key turbulence causal factor specific to that cell as the basis.

Once the basis of focus is settled, then the third dimension of time would come into play. The manufacturing process, both at the global level and at the local or cell level would be re-designed in order to speed up the process. At this stage the system design would incorporate those 'lean manufacturing' principles like JIT/kanban, level scheduling, flow lines, short change over times and multi-skilling as appropriate. (The three dimensional - focus, turbulence and time - approach to manufacturing system design has been written up as a paper - Bhattacharya et al 1996b).

Underlying the entire process of manufacturing system redesign would be the turbulence monitoring and re-invention process, that would seek to monitor the key turbulence factors. A breach of the tolerance levels would signal that local or cell based re-invention needs to be carried out, without changing the overall manufacturing pipeline configuration which is external product-market driven.

Combining this new approach to manufacturing systems design with the earlier discussion on the need to adopt a process focused approach to strategy development and identification of the 'desired' competencies as against the 'existing' ones, a five step approach emerges. This integrated approach is summarised and compared to the traditional approaches in Table 5.

Table 5. Summary of An Integrated Approach to Manufacturing System Design

Steps in the New Approach	The Traditional Way
1. Adopt a process based approach to strategy formulation with priorities driven by 'desired' competencies for existing or new product-markets and not 'existing' competencies.	1. Functional strategy formulation with market driven priorities, and/or strategy to leverage existing competencies in new product-markets
2. Primary level 'focus' of the manufacturing process, using 'product-market' grid.	2. Primary level focus of manufacturing process using market driven priorities.
3. Secondary level or local cell level focus using the key turbulence causal factor as the basis, a bottom-up focus approach.	3. Uniform market driven flexibility designed in across the entire pipeline, a top-down approach.
4. Design the local or cell level pipeline to speed the process.	4. Speed of process is only now becoming part of the process design.
5. Underline the newly designed process with localised or cell level turbulence monitors to trigger local re-invention when the turbulence increases beyond tolerance level, supported by continuous improvement process.	5. Small mis-alignment between process design and competitive priorities corrected through continuous improvement.

This new integrated approach resulted from the experience developed through the work in Companies D and E [13] and was not developed prior to starting the work in these two companies. That is why, from a pure research point of view, the method is not fully validated. However as Report 10 would show, the concept of turbulence and re-invention had great relevance to both companies and in both companies 'time' was used as a strategic driver to speed up the process. The concept of focus at the global level is well known and was used in Company D while the concept of local or team level focus again had relevance to both companies as the case studies show. Thus, the need to have an integrated approach that

[12] A simple, visual and yet useful tool is the product-market grid developed by John Puttick (1993) and used in the analysis carried out in Company D and described in Report 11.

[13] Companies D and E have been used to present the analysis of the 'internal' context and have been discussed in Reports 11 and 12 respectively.

combines all these seemingly independent factors was a powerful learning point and such an approach is a key innovation of this portfolio.

1.6.2 Case Studies in Manufacturing Systems Design

The manufacturing systems design project was undertaken in Companies D and E. Company D manufactures knitwear and sells to a leading high street retail chain. It has a turnover of about £100 million with 8 manufacturing sites. Company E is a leading manufacturer of tractors in the UK. While the project encompassed the entire manufacturing process in Company D straddling 8 different manufacturing sites, the scope was restricted to the component machining area in company E. Presented below is a brief discussion of the problems faced by each of these two companies and the improvement recommendations in each case.

1.6.2.1 Company D

The detailed story of Company D is presented in Report 11. The first step was to carry out a preliminary analysis of the organisation which suggested a large number of issues ranging from very long lead times for both new product introduction and product supply, managerial and logistics problems caused by multi-site and fragmented production and functional organisation structure. The manufacturing sites did not have any product focus and each site concentrated on the different stages of the manufacturing processes like knitting, Rough Make-up (RMU or pre-assembly) and Final Make-up (FMU or final assembly), also had to deal with multiple three knitting technologies. The culture was outdated in comparison to 'lean manufacturing' principles, with a highly hierarchical structure and piece-rate payment system for its operators.

Earlier discussion on process oriented strategy process had highlighted how the market requirements had changed and thus the competencies required by this company were very different from the strengths of the company. It was clear that Company D's manufacturing system, based on limited standard designs, stable volumes and long lead times had become totally mis-aligned with the market requirements and as such needed a virtual re-design.

The preliminary analysis was followed with a brainstorm of senior managers of the company and the two key business processes of New Product Introduction (NPI) and Garment Make were identified for further analysis. Report 11 concentrates upon the Garment Make process, in which I was involved.

As the next step and to give a strategic direction to the detailed analysis, a manufacturing strategy workshop was organised with the management board of the company. After identifying the competencies 'required' by the market, as opposed to existing strengths as mentioned earlier, two key manufacturing system re-design drivers were identified. First, manufacturing lead time was to be reduced from 6 weeks to 2 weeks or less, and second, the principle of teams/cells was to be adopted. Another key conclusion from this workshop was the fact that the company did not have one homogeneous product-market as had been consistently assumed, which emerged by using the 'focus' grid (Puttick 1993). This tool clearly indicated three product groups as shown in Figure 4, each with distinctive characteristics in terms of volumes, styles/design content, and flexibility requirements. Both the application of the tool and the results were new to the company.

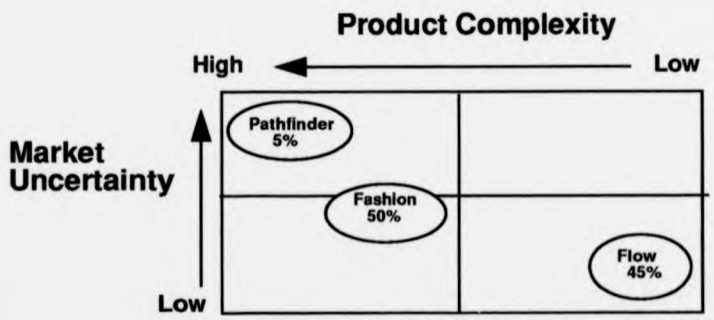


Figure 4. Focused Product Groups in CVK

Equipped with these conclusions and strategic direction, the project team undertook an analysis of the current situation with respect to

- characteristics of the three product types in terms of the customer call-off pattern and the consequent specific manufacturing flexibility requirements.
- the factors causing turbulence on the shop floor.
- the production planning and control system.
- the lead time across the three technology routes of producing a garment using TBPM technique.
- and the organisational structures, team boundaries and reward and recognition system.

and came up with a series of recommendations on each of these areas.

The problems, analysis, solutions and potential benefits in each area are summarised in Table 6.

Table 6. Company D : Summary of Methodologies/Analysis, Findings, Solutions, Benefits and Implementation

Methodologies/ Analysis	Findings	Solutions	Potential benefits	Implementation
Product Focus study	Three types of products - pathfinder, fashion and flow, each with separate call-off pattern, volumes, manufacturing flexibility requirements.	Develop NPI to recognise the differences, develop focused flexibility in RMU/FMU teams.	Minimise turbulence caused by changes in product-mix and RMU/FMU skill constraints.	Being considered by Factory Managers.
Manufacturing Focus study	Turbulence caused by mix of technologies, loss of control due to functional and multi-site (8 sites) manufacturing, high WIP and long lead times.	knit-to-box or 'hard-linked' sites focused on one technology.	Improved control of entire product leading to improved quality, reduced WIP and lead time.	Partial implementation of plan to reduce to 5 technology focused sites.
Merchandising and Sales study	Actual call-off different from contracted sales-flow.	Proactive merchandising using shortage sheets passed on by the customer.	Would enable quick response and potential sales gain.	Plan to be implemented by 1997.
Study of production planning and control	Centralised production planning on aggregate volume based on knitting capacity. Often a mismatch of knitting and Make-up	Plan at colour and size level. Plan for knitting and Make-up capacities. Decentralise planning partially to give more	Planning and control is directly linked to characteristics of customer order and remove turbulence caused by mismatch	All recommendations are under consideration. A WIP control system is planned to be

	capacity and skill constraints. No production control except aggregate volumes.	control to FMU factories Control at batch level with batches linked to customer order.	between manufacturing capabilities in terms of capacity and skill-mix and customer requirements.	implemented in all factories by 1996 with the ability to control batches.
Lead time study using TBPM	The lead time for FF and Shaped technology varied from 5-6 weeks to 3-4 weeks and WIP 8 weeks and 5 weeks respectively against the strategic target of 2 weeks or less.	Knit smaller batch (as close to 30 doz. as possible) in size ratio, transfer small batches, introduce Style-by-Line (refer Report 11c for details) until teamwork is established in the RMU/FMU, plan dyeing off-line.	The lead time can be reduced to 2 weeks for FF and less than a week for Shaped technologies with corresponding reduction in inventory. This would also improve on-time availability for customer call-off.	Lead times have been reduced to 4 days for some Shaped styles. Average lead times are 3-4 weeks for FF and 2 weeks for shaped. Customer service has improved as reflected by reduction in order cancellations.
Seasonality Study	Huge volume turbulence caused by seasonality (65% -70% of sales in autumn season) which in conjunction with high break-even point has led the company to adopt 'make to stock' policy with its attendant risks and high inventory costs.	With the reduction in lead time, partial make-to-order should be explored, the benefits from that policy could justify 'capacity headroom' to enable adoption of the policy.	Would reduce inventory levels and attendant risks, currently reflected in high end-of-season stocks sold as seconds.	A computer model to analyse the trade-off between cost of additional capacity and benefits of make-to-order is being developed.
Manufacturing organisational structure analysis	Functional structure and layout, most functions centralised resulting in long lead times and high quality costs.	Business Unit structure in knit-to-box environment with complete control over the product and some control of planning. Teamwork within RMU/FMU with control of planning and quality.	Better business control by Factory Managers, ownership of quality and improvement of work life for operators. Lead time reduction as less number of 'hand-offs'.	Pilot implementation at one site resulted in control of a style at size and colour level, improved factory performance in terms of indirect costs, absenteeism and quality.

At the primary level of focus, a number of integrated technology focused knit-to-box[14] sites were proposed where possible. Where such physical focusing of the entire process was not possible due to asset re-location constraints, managerial focus was advocated such that one manager was responsible for the entire pipeline from knit to box even though the process was located over two sites. Technology based product focusing was selected as a mix of

[14] The manufacturing process consists of three (four if the garment is dyed) sub-processes, which were set up in a functionally oriented layout across different sites. Knit-to-box sites integrates these processes together into one site or two sites which are 'hard-linked'.

technologies caused major turbulence in the manufacturing sites. This technology orientation was in contrast to functional specialisation like knitting and make-up at individual sites. Product focus was not chosen as it was difficult to accurately estimate the aggregate volumes of the three product types - pathfinder, fashion and flow.

At the next level, teams in knitting and make-up were proposed in a major shift from the current functional layout. It was proposed that teams should be focused on the three product types. To reduce lead time to 2 weeks or less, a number of recommendations were made on launch and transfer batch size, integrating some of the decision points and taking the dyeing planning process off-line, batch planning and control at volume, colour, and size level rather than the current system of planning only at volume level. This meant that the work could be 'flowed' through the cell emulating JIT to a certain extent. Since teamwork is a long term solution and requires long term commitment and resources, an intermediate solution called Style-by-Line was proposed for Make-up which could help reduce lead time and inventory but did not have the flexibility of teamwork.

These major recommendations along with those listed in Table 6 were taken on board by the company. Some of these recommendations were piloted with mixed success as discussed in Report 11. The most successful implementation resulted in lead time objectives being achieved. Simultaneously, it was decided to create a 'footprint' of the factory of the future at one of the sites before rolling it out to other sites. Pilots in this site clearly showed the benefits of following this integrated approach to manufacturing system re-design. At this site, the lead time was reduced to 1 week from 5/6 weeks, WIP inventory was lowered to 1 day in the team as compared to an 8-12 days in the old bulk feed system, indirect costs came down by about 15%, there was lower employee turnover and absenteeism and quality as measured by 'returns to line'[15] improved from an average of 11% before introduction of teamwork to about 3% after teamwork was implemented. However top management still remained wedded to their traditional measure of individual efficiency, and as this fell to an average of 60% against a budget of 75%, the other cost reductions and strategic benefits were given lower priorities and so a distorted picture was seen.

On the other hand, failures to implement some of the other improvement proposals like batch production control, proactive merchandising, batch planning and extension of teamwork were a result of management of change issues like poor communication, lack of consensus among leaders, wrong performance measures and reward systems, which are similar to the typical reasons listed in published case studies on failures of major change programmes (Kotter 1995).

Even though the new multi-step approach to manufacturing systems design described in this report was developed as an integrated methodology after the commencement of the project, Company D illustrates the utility of adopting the different steps in this new approach. The concept of focus, though not new in itself, was very innovative for the company as was the use of 'time' as a strategic driver. The idea to measure turbulence at local level, as a means to flex the built-in first-order flexibility - which itself is new to the company - is now part of the management's lexicon (see Report 10 for details). Some of the well known lean manufacturing principles like teamwork, flow lines, achieving flexibility through capacity headroom, simple

and decentralised planning which were part of the recommendations were also new to the company culture. Preliminary benefits were clearly visible from adopting such an integrated approach and full-scale implementation of all the proposals should enable the company to become highly competitive.

1.6.2.2 Company E.

The case of Company E who approached WMG to help them improve the performance of the manufacturing cells in the machining areas is presented in Report 12. The company was disappointed that even one and a half years after the product oriented cells had been put in place, the performance of the machining cells was falling as indicated by an increase in :

- arrears which reflected missed due-dates
- emergency sub-contracting from the cells
- inventory levels.

The company originally wanted the cell structure to be taken as a 'given' and to look for measures to improve performance within each machining cell. However, it was suggested to the company that rather than jump straight into the cells, a systems approach ought be taken to identify the problems which could reside not only within cells but outside the cells. Preliminary analysis of three cells confirmed this view and also suggested that different cells had different types of issues and possibly different causal factors. Consequently the bottom-up concept of 'turbulence' mentioned earlier in the report (and discussed in greater depth in Report 10) was developed as an analytical framework to identify and to get a measure on the specific problems in each cell and their causal factors.

The next stage of the project was to carry out a more detailed study of the problems in each of the 17 machining cells. However, unlike Company D where it became clear from the preliminary analysis that the manufacturing system was totally unsuited to the requirements of the market and desired competencies, it was not very clear what were the problems in this company. Three approaches were taken to identify the key issues

[15] At the end of each line all the garments go through quality checks and garments with defects are returned

- Cell level turbulence study
- Study the usage of 'time' across the manufacturing process using TBPM
- Carry out a study of cell characteristics - parts usage, lead time of parts, and production flow analysis (PFA - Burbidge 1989) vs cell performance

The methodologies, findings and possible solutions and implementation are summarised in Table 7.

The analysis revealed that at the general level, manufacturing turbulence had increased due to gradual increase in product volumes and variety over the period since the inception of cellularisation. Specifically, the company had experienced a 50% increase in volumes and a 35% increase in variety and this had been reflected by similar increases at the cell level. Consequently many of the cells had, in effect, become 'de-focused', despite increases in their capacity. This consequently resulted in an increase in arrears, excessive inventory both WIP and finished, and a greater frequency for unplanned sub-contracting out of work from the cells.

Table 7. Company E : Summary of Methodologies/Analysis, Findings, Solutions and Implementation

Methodologies/ Analysis	Findings	Solutions	Implementation
Study of cell level turbulence. (The study was largely qualitative as the methodology was under development).	Each cell had its own set of problems and the level of the problem varied between cells. For example, one cell suffered from volume turbulence while another suffered from mix turbulence (defined in Report 10) and even between cells suffering from volume turbulence, the level could differ. There were also some inter-cell issues like inventory record accuracy, production scheduling.	Individual cells required 're-invention' specific to its turbulence types. This would be undertaken with the participation of the area managers and the cell leaders. Project teams to be set-up to look at the intra-cell issues.	Implementation started after the analysis was completed but did not pick up speed as desired and was restricted to intra-cell issues only.
Cell Characteristics vs performance study • parts usage	Parts usage study showed that most of the cells had long 'tails' or 'stranger' parts. MLT distribution showed large	Those cells having large % of stranger parts should review their make vs buy policy. 'Unfocused' job-	Implementation on two of the three recommendations - cell re-design and lead time

back to the line for mending.

distribution • manufacturing lead time (MLT) distribution across parts • Production flow analysis (PFA)	standard deviation. PFA clearly indicated that some cells were no better than 'job-shops'. There did not appear to be any relation between a cell's characteristics and its performance, except the few large 'job-shop' type cells had the worst performance.	shop cells required cell re-design. Review the actual lead time vs the MRP system lead time to remove anomalies.	review has started. The rationalisation of lead times has resulted in reduction in finished inventory for the pilot parts.
Usage of 'time' across the manufacturing process	The actual processing time was a fraction of the lead time. High lead time was a result of large batch sizes and waiting times.	Small transfer batches coupled with temporary flow lines were proposed. For some of the runner parts, 'kanban' was recommended.	Lead time reduction and kanban implementation was carried out on selected pilot parts. Some parts saw 50% reduction in lead times and attendant inventory levels. Kanban parts showed improved customer service.

Further evidence of system instability was observed in the turbulence in the schedule for not only final assembly, but also for the sub-assembly and machining cell levels. This schedule turbulence, characterised by the change in the schedule first forecast six weeks out to that which is cast during the week of actual production, caused a variation of about 10% at final assembly and sub-assembly level.

In contrast, the knock on impact of this turbulence at part level was much higher, as much as 60% in some cases. This illustrates the Forrester effect (1975) within a supply chain that is internal to a business and has also been reported by other researchers (Towill 1994). It is apparent that the turbulence is felt most strongly at part level (i.e. upstream within the internal supply chain) and less so in the final assembly and sub assembly operation. Another factor that contributed to this effect was the different scheduling approaches being applied: whilst the higher level assembly operations are tightly coupled with a sequenced Kanban style supply, the component machining cells were being scheduled through MRP.

The issues were categorised into six areas, namely; parts mix in cells, intra-cell parts flow, manufacturing lead times, planning and scheduling system, inter-cell parts flow and supply chain management. The pilot implementation was limited to two areas : improving the cell 'focus' to reduce turbulence and lead time reduction.

Within Company E, mixed part routings in those cells processing a large number of parts and machines could cause major turbulence when volumes or mix or schedules were changed. These cells were like big job shops making their management very complex. Using production flow analysis as the means to analyse the part-machine relationship, parts and machines were planned to be clustered into focused sub-cells, in effect re-inventing the cells. This was expected to minimise the turbulence and to simplify the management.

In Company E, lead time reduction proved effective for runner parts. Instead of the conventional 'lot for lot' based MRP schedule the manufacturing system was redesigned to produce the 'runner' (Parnaby and Herbim 1987) parts using a Kanban based production. Additionally, part launch batches and transfer batches between elements of the process were designed so that the focused sub-cells could function as temporary dedicated lines. In the three pilot cells, adoption of this approach had led to average Manufacturing Lead Time (MLT) reduction by 10%, 14% and 20% respectively (for some parts the reduction was as high as 50%) with attendant decrease in WIP even whilst maintaining the service levels to downstream cells. Such a reduction was achieved even though only a handful of 'runner' parts had been affected in these cells. The principles of lead time reduction, Kanban implementation and cell focus were documented and are being used for expansion into other cells.

The one apparent failure of the project was the slow speed of implementation which was primarily due to the lack of ownership by the senior managers.

The overall systems methodology adopted in Company E was supported by various tools and techniques, some well known and others developed for the purpose. Even though tools like Pareto analysis of the parts and PFA are well known, they were used for the first time in the analysis of cells in this company. Similarly, the lean manufacturing principle of kanban though known by Company E had not been implemented successfully and so was to some extent new in their experience. On the other hand, the methodology of measuring turbulence locally within the cell to identify problems specific to the cell was developed after being faced with the dissipation in performance in the machining cells. TBPM technique and the use of 'time' as the driver of process improvement was new to the company and took time for the cell leaders to accept and to apply it.

To conclude, the use of all these tools and techniques as part of a systems approach and the implementation of the recommendations on the pilot parts showed clear benefits in terms of reducing both lead time and inventory levels and improving service levels for those parts which are supplied through kanban.

1.6.3 People Issues and Management of Change

One of the key learning points from the projects is that it is relatively easy to design the technical change based on well defined business performance criteria, but it is another matter to carry out the implementation. Consider each of the following instances. The FWS research project indicated that while it made business sense to increase the level of outsourcing and design/development delegation, there is resistance from the design and manufacturing people, and understandably so. In one of the SMEs (Company C), the marketing manager was reluctant to even consider some re-positioning options since he 'feared' that some of the customers may not like it. In the case of both Companies D and E, the pace of implementation of recommendations was very slow as people were not prepared to accept the change and take ownership of it, or actively opposed it through fear of the unknown. A typical example of the latter was the reluctance on the part of the factory managers to remove the individual incentive payment system which was the root cause of several problems in manufacturing.

On the other hand, one fact about the environment in which the organisations work came out loud and clear; manufacturing firms are being faced with increasing levels of complexity and uncertainty. But it is true that any system, which includes people, works best in a stable environment. As Stevenson and Moldoveanu (1995) say, unless people are assured a predictable work environment, how can they concentrate on creating value? To them virtual enterprise threatens predictability the most. Because people want stability, they cannot cope with too much change at the same time. A cell manager in Company E used the term 'initiative graveyard' to characterise these failures. However the complexity and uncertainty of the market place clearly engenders unpredictability within the organisation. The organisational responses outlined in this report are a consequence. How to resolve this dichotomy becomes a key issue.

Clearly an organisational culture is called for which does not fear change. Unpredictability is seen as a source of opportunities. Nohria and Berkley (1994) have called this external characteristic of the environment 'disequilibriums' and call for a proactive organisational culture in which the employees rather than fearing the need for continuous and rapid changes actually develop organisational processes which help them to monitor such disequilibriums and re-engineer the business as required. Drucker (1992) says that every organisation has to build the management of change into its very structure. In Company D the factory managers have realised that the days of few styles and long production runs are gone and they will have to proactively plan for configuring their factory for future wide range of styles. Unless they do so, they would not have a factory to run. The same cultural change needs to permeate downwards to the operators.

The culture of unpredictability and re-invention means that organisational processes and manufacturing systems would always be under pressure. Organisational Change would not be a one time exercise but a continuous process. In this type of culture management of change becomes a critical issue. The subject of management of change is probably one of the most researched topics within organisational processes. Various theories and frameworks have been advocated. Others have come up with packaged solutions like the 'model of excellence' advocated by Peters and Waterman (1982).

The experience in facilitating change in both Companies D and E highlights the need for a holistic approach to management of change. It is easy to concentrate on 'technical change' and divorce it from 'people change', which is a certain recipe for disaster, and in that respect the philosophy of Total Quality Management in integrating the two should be followed. In Company D's case, they have implemented the new manufacturing system without supporting people systems like reward and recognition, performance measurement, training and education, extensive communication which clearly restricts the long term benefits and flexibility of the system and also makes it more difficult to install the new people systems at a later date.

In Report 8 I have expanded this argument and proposed that one way to overcome this is to construct a 'life-cycle' of the change process which advocates the application of different theories and frameworks at different stages of this life-cycle. This life-cycle has four stages of *Need Analysis, Build Critical Mass, Energise and Institutionalise* and at each stage a mixture

of various approaches is used as seen to be appropriate, making sure that the technical change and people change go hand in hand. The characteristics and the potential - since the actual activities used would vary from one company to another - activities in each stage of the life-cycle are summarised in Table 8. The innovation comes not from the characteristics of each stage or the activities to be undertaken, which are well known, but in constructing the life-cycle which provides a strategic framework where different theoretical frameworks co-exist, specific to the life-cycle stage. The key to using this management of change approach is the recognition by the company that the shape of the life-cycle and the effort and time for each of the four stages would vary from one company to another, and has to be understood before launching the change programme.

Table 8. Characteristics and Activities in the Change Life-Cycle

Change Stage	Need analysis	Build Critical mass	Energise	Institutionalise
Characteristics	Definition of the 'desired' state and 'top-level' changes needed	Build Change 'Template' by identification of impacted areas, 'getting on board' the key people in impacted areas at all levels, identification of desired managerial behaviour and competencies	Programs for implementing the desired changes, using the identified managerial competencies, leading to the practice of desired behaviour in all the impacted areas	Change Template is the way of life. Supporting the 'new way' through corresponding changes in supporting systems, review and evaluation to see if the changes have met the objectives
Potential Activities	Visioning-consensus on direction and desirability of change, external scan of the environment, internal review of organisational processes, team for working out the specifics of change, communication for contribution and buy-in to the vision	Cultural diagnosis to understand attitude to change, understand the history and impact of past changes - perform a force field analysis to identify the resistance to change, develop consensus on structure to monitor and evaluate the change process, 'leader' to drive the change, 'sub-leaders' accountable for parts of the change process, communication and education to let impacted persons connect and contribute to designing their own roles in the change process, pilots where required	Focus on 'goals/', implementation of new work structures, focused skills training, upward communication from impacted people, clarifying the new roles, strong leadership style changing to participative	Cultural diagnosis to understand attitude to and success of change, new support systems to facilitate institutionalisation, need based training provided, more participative leadership

Unfortunately, in the case companies reported, the companies preferred to adopt a piecemeal approach rather than this concurrent approach and this may explain some of the limitations of the improvements achieved by both companies.

Personally, I have come to believe that only those organisations who possess a culture which facilitates and encourages change rather than stability will remain successful. As Scott Morton (1991) contends, one of the challenges for an organisation in 1990s is to understand one's culture and knowing that an innovative culture is a key first step towards an 'adaptive' organisation. Both Companies D and E have some way to go to achieve this.

1.7 The New Manufacturing and Concluding Remarks

In this report, I started by outlining some of the factors that are driving change in the manufacturing industry. While some are customer driven like the need for speed and customisation, others are developments in the process technologies which provide enhanced flexibility in manufacturing. Development in manufacturing management techniques like JIT/kanban, cellular manufacturing are also driving change and lastly there are change drivers arising out of the changing relationships between trading partners.

Arising out of all these different change drivers, three key issues were identified :

- the trading relationships which provide the external view and the context within which the manufacturing organisations operate
- the impact on the strategy process of these changes in supply chains and the focus on processes as organisational building blocks - the external-internal link
- integration of top-down traditional product-market analysis with bottom-up turbulence minimisation and strategic imperative of speed in the design of manufacturing systems, which provides the internal analysis of manufacturing organisations

In this portfolio, an attempt has been made to explore each of these key issues facing manufacturing organisations, through development of best practice models of trading relationships, alternative trading structures, strategy development methodologies, analysis tools and techniques, which have been validated either through research or application. Many of

these methodologies, tools and techniques were new or brought together a new perspective to existing methodologies and were also innovative in their application to the case companies, as summarised in Table 9, and delivered strategic benefits to Companies B and C, strategic and operational benefits some of which are quantifiable to Company D and quantifiable operational benefits to Company E. These benefits are summarised in Table 10.

Table 9. Innovation and Value-addition from this Portfolio

The Context	Current knowledge	Innovation / value-addition	Relevant Report nos.
External Trading relationships between companies	Discrete information about the practices of the traditional western, Japanese and the western style supply chains and their individual characteristics.	Development of a holistic 'best practice' model independent of any trading structure label. Identification of a new multi-customer trading structure that incorporates features of all the four theoretical trading models.	Reports 2 and 3
External-Internal link Strategies for growth	Growth strategies for entering new markets, getting customers or increasing sales of current products to the same customers (not considering the diversification strategy).	Re-positioning methodology which seeks to find growth strategies for suppliers based on increasing added-value of current products, taking advantage of the trend to increase outsourced value by the final assemblers.	Reports 4, 5, 6 and 7
Internal Strategy formulation process and manufacturing systems design	Functional strategy flowing out of overall business strategy. Manufacturing systems design based on the concept of focusing and alignment - focusing on a narrowly defined competitive priorities and manufacturing system designed to be aligned with them, providing a uniform set of rules for the entire manufacturing pipeline, with continuous improvement to correct minor misalignment.	Process focus strategy formulation process, identifying the desired competencies rather than leveraging existing ones. Multi-dimensional approach that integrates the traditional top-down focus approach with local cell based turbulence minimisation with time compressed manufacturing process, supported by re-invention to correct major cell level misalignment caused by excessive turbulence.	Reports 8, 9, 10, 11 and 12

The umbrella of issues explored in this portfolio provides the context within which manufacturing organisations operate today and this widely ranging context is what I have termed The New Manufacturing. The areas of the context in themselves are not fundamentally new. Supply Chain management, core competencies, systems approach to manufacturing design and process focus are well known concepts. However, the portfolio adds to this body of knowledge in each of the three research areas and brings them together into a cohesive pattern. The context of New Manufacturing as developed in this portfolio also highlights the differences with the traditional understanding of manufacturing.

Table 10. Strategic and Operational Benefits in the Case Companies

Company	Strategic benefits	Operational benefits
Company B	By introducing the concept of 'value' route to growth, Company C is exploring the possibility to form an alliance of its supply chain members so that it could offer a full range of services as a first tier supplier, effectively re-positioning the company	
Company C	Using the concept of 'value' route to growth, this company has initiated discussion with some of its customers in the food sector to bring in additional value adding activities in-house, effectively re-positioning itself in this industry segment.	Unable to re-position itself through adding 'physical' value, company is seeking to increase 'service' value by providing differentiated service to different type of orders from customer in the non-food sector.
Company D	Develop process strategies for the two key processes using 'time' as the driver. Re-design the manufacturing system to deliver the lead time objective for the garment supply process, a key proposed (partially implemented till date) strategic change being an integrated manufacturing process with rationalisation of functionally focused plants.	Lead time reduced from up to 6 weeks and WIP from up to 8 weeks to less than 3 weeks and 4 weeks respectively. In addition, at a pilot site, indirect costs reduced by 15%, quality improved 11% rejects to 3%, and overall customer service improved reflected in less number of order cancellations.
Company E		Reduction in MLT by as much as 50% for some pilot parts resulting in MLT reduction by 10%, 14% and 20% in the three pilot cells, better customer service as reflected by reduction in shortages for pilot parts scheduled through 'kanban'.

Traditionally manufacturing was narrowly defined as the function within the organisational boundary that 'produced' the physical product, i.e. converted the raw material into the final product. That is to say production and manufacturing were synonymous. Manufacturing was a 'black box', rarely understood outside its boundary, with only one function - take an order and

produce as per the order. The processes of designing the product, sourcing the raw material, planning for the material and information flows, developing strategies to meet customer requirements, were all seen to exist outside the black box. However the discussion in this report brings out the close linkages and complementarity of production competencies between trading partners, the need to integrate the various processes which go towards satisfying the customer and incorporate both strategic and operational imperatives in the manufacturing systems design. To paraphrase a popular expression, 'manufacturing is no more an island'.

Thus the New Manufacturing is no more the narrowly understood function of production. Drucker recently defined manufacturing as the process that converts things into 'economic values' (1990). Giffi et al (1990) found that world-class organisations have a systems perspective which treats manufacturing as part of a process which establishes the customer requirements, prepares products which are fit for use and delivers satisfactorily to the customer. In another view, manufacturing takes on 'service' roles like logistics, after sales service, etc. (Chase and Gavin 1988). Kuhnle et al (1995) talk of factories as a service provider, who are not in seclusion any more, like a big 'black-box', but have close interactions with customer related functions and processes.

The context of New Manufacturing as described in this report incorporates the entire value chain, starting from conceptualising the product to delivering the manufactured product to the customer, within the proprietary boundaries of the organisation - the internal level. And this value chain is then extended over the trading partners - the external level. It goes beyond the narrow boundary of producing the product and includes service functions as well as dealing with suppliers and customers. In the New Manufacturing context, if a component supplied by a supplier fails on the line side of the customer, the line manager and supplier manager get together and solve the problem directly. There is no third party intermediation. The supplier and the customer get together and jointly plan their strategies in order to maximise the value to the customer. Process improvements are carried out across ownership boundaries. Integrated methodologies are adopted which minimise turbulence across the entire supply chains and not only in one part of it. The entire supply chain becomes fast and responsive. Each part of the process within the ownership boundaries of trading partners are focused to provide complementarity of skills and competencies.

Thus, from an organisation's perspective the level of analysis of manufacturing is at two levels, the external and the internal parts of the value chain. With increasing uncertainty and unpredictability, the fragmented internal value chains will become less stable, will be more core competency focused, will be re-positioned to customise the value stream for each supply chain, and will be organised around integrated time compressed processes. Re-invention of the manufacturing system incorporating both technical and people change in order to minimise turbulence would be a key organisational capability. Those value chains which have these capabilities will be the most competitive.

Coming now to the subject of future developments from the portfolio, Table 9 presented the additions to the existing body of knowledge on the subject of manufacturing by this portfolio. However, it is not claimed that the approaches, methodologies and tools which constitute the additional knowledge cannot be further developed or improved and made more robust. Ideas for development/improvement in each of the three areas covered by the portfolio are presented below.

In considering the 'external' context area, while the holistic eleven-characteristic model of supply chain used in the FWS research project was partially validated through the observed trends towards the best practice, the model could be enhanced by actually quantifying and measuring the relationship between the performance of supply chains and the closeness to the theoretical best practice, as presumably, supply chains closer to the theoretical best practice model should show superior performance. The case study of the multi-customer supplier which presents several interesting theoretical issues like the stability or convergence of the emerging structure needs to be further supported by study of similar suppliers in order to confirm whether the results are unique to this company, or industry or more widely applicable. And this in turn leads to another interesting research question whether the shape of the emerging trading structure is a function of the industry, and if yes, the industry factors which are determinants of the new shape.

Looking at the link between the external and internal context area, while the applicability of the 're-positioning' methodology was shown through Company A and the benefits of using this approach to the strategic debate within a company was demonstrated through Companies B and C, the methodology itself evolved as more experience was gained from understanding of

the changes taking place in supply chains and how suppliers could respond to these changes. Hence, the next step would be to 'test' the methodology more fully by applying it in its developed form from the beginning with another supplier, including a full cost-benefit analysis of the re-positioning options.

In considering the 'internal' context area, the business process focused strategy methodology was developed to address a perceived weakness in the traditional functional based approach. The proposed methodology attempts to tie together the two key strategic approaches of core competencies and business process orientation, and a qualitative application of this approach was performed in Company D. However, further improvements can be made. On the one hand, 'content' research is required to identify and to develop the decision variables of the key business processes and their link to current and desired competencies. On the other, the 'process' for implementation of this methodology could be enhanced by the development of well defined steps and work-sheets, which could aid its application.

The multi-step manufacturing system design, (like the re-positioning methodology), evolved over time as greater understanding and experience was gained through dealing with manufacturing problems in Companies D and E. Thus it has not been fully validated in a fresh empirical situation. Two of the three concepts in this integrated approach, namely 'focus' and 'speed' are well known and thus require no further validation. However, the impact on manufacturing performance of implementing the concept of turbulence and re-invention is yet to be fully assessed. While all the three concepts can be implemented by themselves, and were in fact treated independently in both companies, a detailed implementation process with worksheets for the proposed integrated methodology, similar to the manufacturing audit process of Platts and Gregory (1992) is desirable.

Notwithstanding these opportunities to improve the methodologies developed in this portfolio, their application in the research project and in various case companies clearly illustrates the number of both strategic and operational benefits that can be derived through their application as summarised in Table 10.

To conclude, the environment facing manufacturing organisations is become more volatile, with higher levels of unpredictability and uncertainty, not only affecting the trading

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To conclude, the environment facing manufacturing organisations is become more volatile, with higher levels of unpredictability and uncertainty, not only affecting the trading

relationships between companies, but also the strategic approaches and the internal operations. Organisations need to respond by developing a culture which seeks opportunity in the instability of the complex environment, and by developing innovative product and process solutions to changing customer requirements in order to survive and prosper. This thesis presents such a broad view of the manufacturing process with methodologies, best practice models, tools and techniques and it would appear that such a holistic approach is desirable if a company is to seek superior performance in the complex environment facing them today.

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Appendix A

Submission of Published Papers to Support the Portfolio

Paper 1 : Benchmarking Trading Processes (paper presented at the bi-annual conference of European Logistics Association, Brussels, November, 1994)

Paper 2 : Suppliers : Proactive Re-positioning for Survival (paper published in Logistics Technology International, 1995)