The system of manufacturing : a prospective study

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The System of manufacturing: A prospective study

by

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Report EUT/BDK/56
ISBN 90-386-0311-8
ISSN 0167-9708
Eindhoven, 1993

INDUSTRIAL ENGINEERING AND
MANAGEMENT SCIENCE

CIP-DATA KONINKLIJKE BIBLIOTHEEK, DEN HAAG

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Eindhoven: Eindhoven University of Technology.
Graduate School of Industrial Engineering and Management Science.
(Report EUT/BDK;56)
With references.
ISBN 90-386-0311-8
NUGI 689
Subject headings: manufacturing systems, manufacturing and engineering.

The System of Manufacturing: A prospective study

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Executive Summary

The manufacturing research and market place viewpoints of the leading industrialised nations of the world have been assessed. These have been mapped to the existing European research initiatives and consumer trends. The authors view is that European manufacturing research must place greater emphasis on total manufacturing business systems development.

Using this perspective the context in which European manufacturing business will be operating and its basis of competition was examined. The report details the primary pressures to which manufacturing will be the subject. These are encapsulated in the concept of customer driven manufacturing business systems.

A substantial effort was deployed to isolate key product and process technological advances, environmental, and market place developments. These are described under the heading 'Manufacturing into the 21st Century'. Probably most significant are the changes in the value chain now emerging which transforms the manufacturing business system and overturns conventional manufacturing strategy and manufacturing metrics. The institutionalisation of the Extended Enterprise is one of the most tangible outcomes. Less obvious outcomes also involve major structural change.

The report identified technical areas for research action and specifies research programmes in each area. The areas are:-

The Extended Enterprise
Concurrent Engineering
Organisational Learning
Investment Appraisal
Manufacturing Information Systems

The research programmes proposed offer generic improved effectiveness to European manufacturing systems. A number of supporting actions are identified together with timescale indicators.

Introduction

This report is an outcome of a study conducted to define technical areas for which research action at CEC level is most appropriate and to prepare a proposal for a global RTD strategy. The study was commissioned by DGXII of the Commission of the European Communities.

The study focuses exclusively on *the system of manufacturing*. Thus there is no attempt to consider the potential for improving the performance of individual activities or operations in manufacturing. Rather the study concentrates on a holistic view of the manufacturing system and defines approaches which seek to optimize system performance.

The structure of the report is as follows:-

- In section 1 we identify the pressures now acting on manufacturing systems and the movement towards customer driven manufacturing systems.
- In section 2 we identify three key issues, namely globalization, environmentally benign production, and evolving business and organisation structures, all of which are driving manufacturing and business systems towards inter-enterprise integration. We define inter-enterprise integration and suggest that it has important consequences in terms of reduced product life cycles, reduced time to market, the need to take a total product life cycle view and the development of appropriate manufacturing strategies.
- In section 3 we identify technical areas for which research action is most appropriate.
- In section 4 we draw some conclusions from the study.

1 A Context for Manufacturing Systems

Skinner (1) reported that "A company's manufacturing function is either a competitive weapon or a corporate milestone. It is seldom neutral... few top managers are aware that what appear to be routine manufacturing decisions frequently come to limit the corporation's strategic options". Later Skinner (2) acknowledged, the situation had changed: "After years of neglect, top management's attention has been captured... the action in manufacturing has been extraordinary in these last five years".

The emphasis on the manufacturing function led to an improvement in manufacturing performance. The "Manufacturing Futures Survey", conducted by Boston University, INSEAD in France and Waseda University in Japan (11) identified significant improvements in manufacturing performance over a range of indicators. Their survey of five hundred companies in the U.S., Japan and Europe pointed to improvement in inventory turnover, level of product variety, delivery reliability, customer service, overall quality, the speed of introduction of new products, manufacturing lead time and manufacturing cost. It is worth noting the performance indicators used to measure improvements - no longer is manufacturing cost the only important criterion.

The performance indicators identified and used in the Manufactuıing Futures Survey are indicative of the pressures placed on manufacturing by todays business environment and discerning customers. Further these pressures are felt by companies across the developed world. The same study reports that "statistical analyses shows few differences in perceived competitiveness across the regions (Japan, U.S., Europe) on such critical variables as conformance quality, product reliability, cost and delivery dependability". The performance indicators subject to the most rapid change were; inventory turnover, quality and customer service, time based competition and flexibility. These might well be considered to be performance measures which reflect most closely the emergence of "lean production"*.

In fact these performance measures reflect some of the pressures now placed on the manufacturing enterprise and the goals which the enterprise adapts. The pressures emerge from the following factors:-

(i) Manufacturing now takes place in a global economy.

- How and where raw materials are transformed is a strategic decision. The decision is complicated in terms of what to make and where to make or buy it, in what is becoming a single global economy. An aspect of the development of the global economy is the formation of strategic alliances between companies. Frequently these alliances include cooperative production agreements.

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* Lean Production is discussed in Appendix 1 of this report.

- Customers are very discerning in terms of price, quality, cost, delivery and the availability of customized features.

- Markets are timebased competitive. Increasingly, for many products, time to market is a critical issue in terms of gaining market share and achieving profitability.

- We are moving towards customer driven manufacturing*. The products of the future will be required in a wider array of models and variations. The expectations of customers in terms of customized features means that the customer is engaged more closely with the manufacturing plant. In a make to order and ultimately an engineer to order environment, the manufacturing plant must be able to deal with orders for customised products from customers.

- Trade barriers are gradually coming down, further opening up global markets. The recent opening up of eastern European markets is important, not only in terms of future markets but also in terms of the needs of those markets. It is likely that the needs of customers in Eastern Europe will be somewhat different in kind to those of the advanced Western European economics. Thus, whereas customization and quality may be important issues in Western Europe, volume and price may be far more important in Eastern Europe.

(ii) Manufacturing systems are required to develop environmentally benign products and processes.

- Public opinion is increasingly aware of the environmental impact of manufacturing processes and indeed the products of manufacturing.

- Legislation will increasingly constrain product and process design in terms of energy utilization, the use of recycleable materials, the safe disposal and indeed the reuse of products at the end of their life.

- Increasingly product liability extends up and down the supply chain.

(iii) Business and organizational structures are under increasing stress.

- The business focus on core activities increases reliance on subcontractors and suppliers.

- The availability of information technology and telecommunications products supports distributed working.

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* Customer driven manufacturing is discussed in more detail in Appendix 2.

- Many of todays manufacturing organizations are designed on vertical and hierarchical principles. The move toward hetrarchical structures is and will continue to displace middle managers. The span of control of individual managers will increase significantly.

- There seems to be some difficulty in attracting large numbers of intelligent young people into manufacturing. For many young people, manufacturing engineering, compared to for example design engineering, is not seen as a rewarding career path.

- The population is becoming older and more experienced, and may have greater difficulty adapting to change.

2 Manufacturing into the 21st Century

Introduction

We have identified in the previous section three clusters of pressures, namely :-

- Globalization,
- Environmentally benign production,
- New business and organisational structures.

These pressures will be discussed in more detail below in section 2.1. We will argue that all three pressures lead to inter-enterprise integration. This concept is discussed in section 2.2. Five important issues of inter-enterprise integration are investigated in section 2.3. These issues are:-

- Reduced product life cycle,
- Time based competition,
- Total product life cycle,
- The need for high quality organisations and people,
- Manufacturing strategy.

2.1 Pressures in the Manufacturing Environment

Globalization is a key-word in manufacturing in the next decade. International competition is rapidly replacing national competition due to open markets, with increased size, accessibility and homogeneity. The reduction of trade barriers, the harmonization of laws, and the improvement of transportation have paved the way for competitors everywhere in the community. *Consequently, local competition operates in the context of global standards.*

Technological developments in manufacturing technology contribute to globalization also. Miniaturization is such a development. Clearly, miniaturization leads to a lower proportion of transportation costs in the value chain. Therefore, manufacturing for remote markets becomes feasible. Further, competitive prices for miniaturized products imply large investments and high volumes. This development too leads to globalization. At the same time, large investments and high volumes lead to more subcontracting and outsourcing.

In the case of increased competition due to globalization, a well known reaction is to search for a market niche in the enlarged market. Two other responses to severe competition are mentioned here:-

- Decreasing product lifecycles
- Increasing added value by improved service.

The decrease of product life cycles is a well known phenomenon. It is a consequence of the fact that high prices are only possible in the introductionary phases of the product life cycle. This is due to globalization, because global competitors have the power to react quickly after the introduction of an innovative product to the market. These reactions enforce shorter product life cycles. Furthermore, today's rapid technological developments make these shorter product life cycles feasible.

Increasing added value by improving service is a frequent response to severe competition. As a first step companies will often increase the variety within a product family, in order to improve customer satisfaction. A second step in the same direction is to add value by providing better information, repair, training and other services around the product. For standard commodity items, this is combined with direct marketing and shorter distribution channels.

For customizable products, a third step towards improved service lies in *customer-order-driven manufacturing * and distribution*. Ultimately, the sales office may be transformed into a multimedia telecommunications service: *the customer will be enabled to drive manufacturing and physical distribution operations as a "prosumer" (proactive consumer) to create a "proservice"(product plus service) for his/her own needs*. In a sense this notion of future manufacturing extends the traditional meaning of the manufacturing system considerably; it re-integrates sales with production, but decouples distribution from sales (see figure 1a and 1b). It is quite probable, that this re-integration of sales and manufacturing will create many opportunities for highly qualified jobs in Europe.

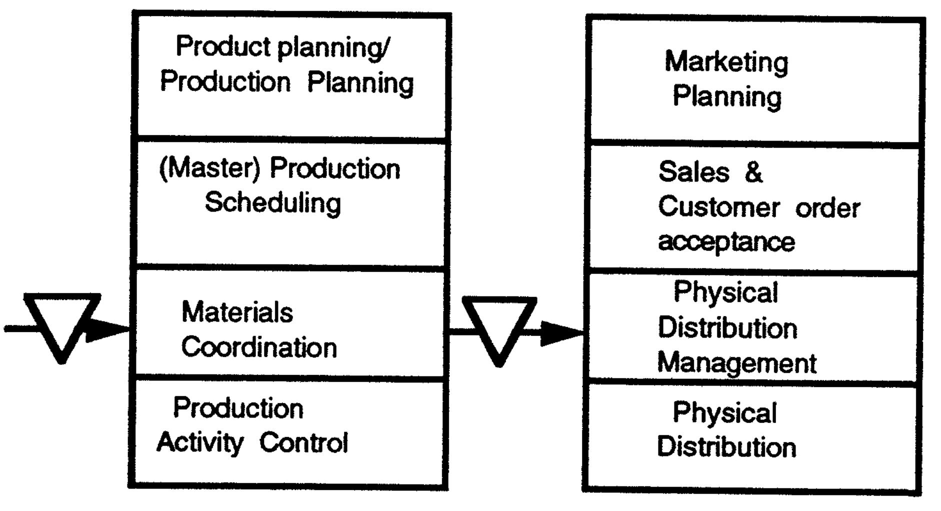

Figure 1(a) Manufacturing Developed from Marketing and Physical Distribution

This reintegration of sales with production can be seen very clearly in the production of personal products, e.g., limb prostheses. For example Hasegawa (3) has speculated on the impact of what he terms "next generation CIM" on the production and sales of shoes. His ideas are outlined in Figure 2 overleaf. The reintegration of sales with production and the emergence of customer order driven manufacturing contrasts strongly with the make to stock approach of "conventional CIM".

* See appendix 2 for a short discussion on customer driven manufacturing.

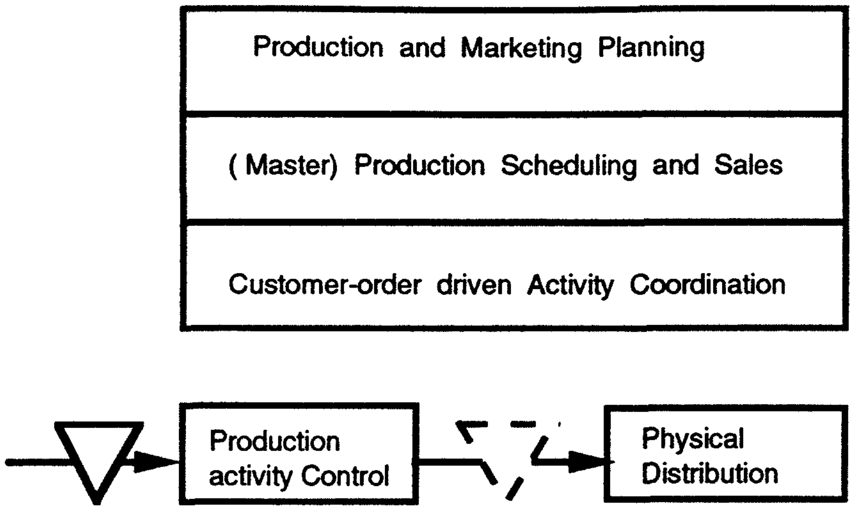

Figure 1(b) Manufacturing and Physical Distribution driven by Customer Orders

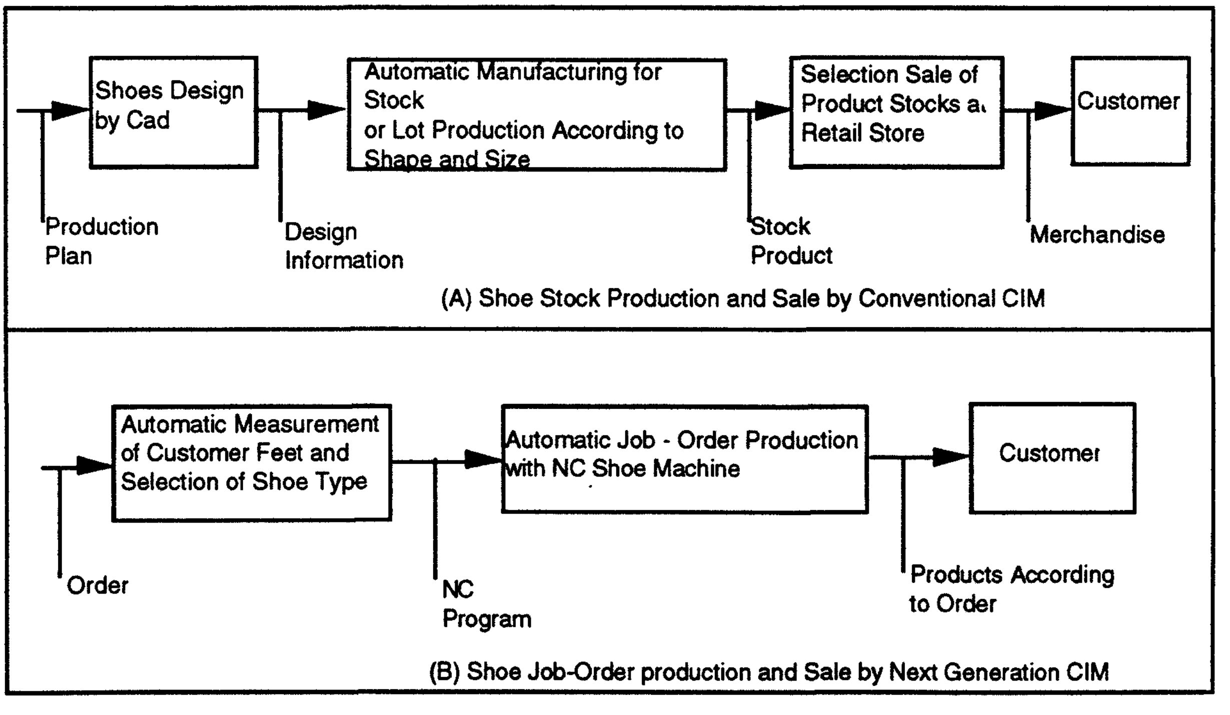

Figure 2 Comparison with Shoe Manufacturing System Between Conventional and Next Generation CIM.

Environmentally benign production is another key-word in this manufacturing systems' prospective study. Society is putting pressure on manufacturers, in order to create production systems which are neutral with respect to the environment. This pressure acts through government regulations and customer requests. It may take the form of legal regulations, economic consequences, and consequences for marketing.

These pressures will constitute a challenge for European companies, to develop new technology and materials. In the long run, environmentally benign production may become a competitive edge. Environmentally benign production will require a shift of paradigm for engineers, accountants, government agencies, and many other parties. As will be argued later in this paper, a further pre-research study is required to put the complete shift of paradigm into a framework for research proposals. However, there is one line of development which is clearly emerging from the environmental requirements for manufacturing as a system: *the object of study should not be restricted to a single plant or production facility, but should include chains or networks of production and physical distribution.* Issues such as design for recycling, refurbishment, environmental costing, and many legal issues can only be studied if the scope of study is enlarged to the chain of value-adding activities, including ultimately disassembly and refurbishment.

The value chain is a useful model to express the business and organisation structures now emerging. It is also a useful model from the point of view of environmentally benign production, and that of globalized competition. We identified earlier a trend towards product-customer integration in the value chain (see figure 1).

To demonstrate some changes in the value chain* , consider figure 3. Suppose that the contribution of each element to the added value of the final product is normalized to 100%. Then figure 3 suggests five effects:

- New materials such as highly-alloyed steel, composite materials etc. will probably lead to an increase in value added in material supply.

- Component manufacturing will probably move towards lower value added, because of the effects of miniaturization and other manufacturing technologies. More complex components with much more functionality tend to become available at low (marginal) costs. Further reduction in the total costs can be expected if large investments in high-volume facilities have been made and if these facilities are run at a reasonable utilization rate.

- Assembly is likely to move towards lower added value also, because much functionality is already available in the components.

- Physical distribution will probably involve lower costs if the interaction between the customer and the manufacturer becomes more intensive.

- Improved service around the product will increase the added value in sales and after-sales activities.

At first glance, figure 3 might suggest that the European Community should not put much emphasis on component manufacturing and assembly. However an indepth and more detailed discussion will modify this conclusion considerably.

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* For a discussion on the background to the "Value Chain" see Appendix 6.

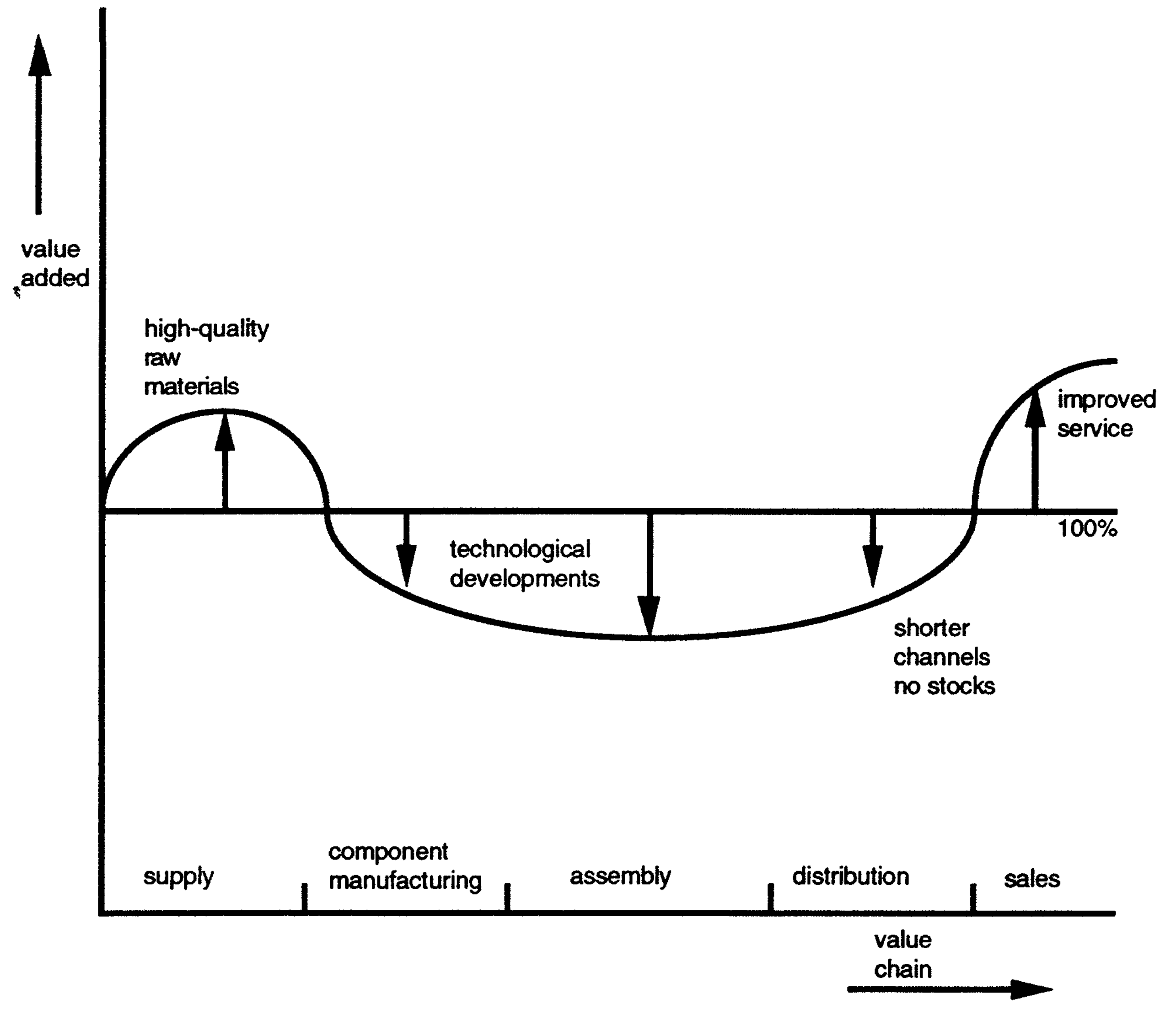

Figure 3 Changes in the Value Chain.

In component manufacturing, there is a technological trend towards manufacturing systems *where the marginal costs of an additional unit is almost zero*. Software is a good example. But more generally, all knowledgeware (books, entertainment, NC-codes, multimedia-applications) has a marginal cost of almost zero. Note that components such as integrated circuits or software represent a considerable part of the added value of many of today's products. Thus, the expected decrease of manufacturing costs is largely a matter of how investments costs are allocated to products. This leads to an important conclusion. If considerable investments are required for component manufacturing, then the party which has made these investments controls the supply chain. This is simply due to the fact that this party can manipulate prices, delivery times and volumes. Therefore, high investment in component manufacturing (including software) should not be left to other parts of the globe if monopolies are likely to occur.

The case for assembly is different. Today's assembly techniques are still largely manual. However, the costs of assembly are often reduced by more intelligent design of components. Furthermore, assembly has become more customer-order driven and therefore adds to the customer-friendliness and flexibility of the manufacturing system.

In figure 4 we show the likely consequences of environmental costing. These effects should be superimposed on the effects of figure 3. No doubt, there will be considerable variances between different industries with respect to these figures. They do not pretend to have universal validity as a scientific law. Rather, these figures indicate the type of value-analysis which it is worthwhile to perform for each branch of industry separately.

Figure 4 shows first of all, that environmentally benign production increases costs -- at least in the first few years. Thus, fair competition requires that we avoid the situation where environmental costing is applied in some part of the world and not in other parts. Secondly, Figure 4 suggests that environmental costing will give rise probably to higher costs of the purchased materials and component manufacturing. However, the environmental consequences of these manufacturing activities have been monitored for several decades, and it should be possible to compute these effects in any system of environmental costing. It is more difficult to estimate the effects of recycling of materials and components to the suppliers.

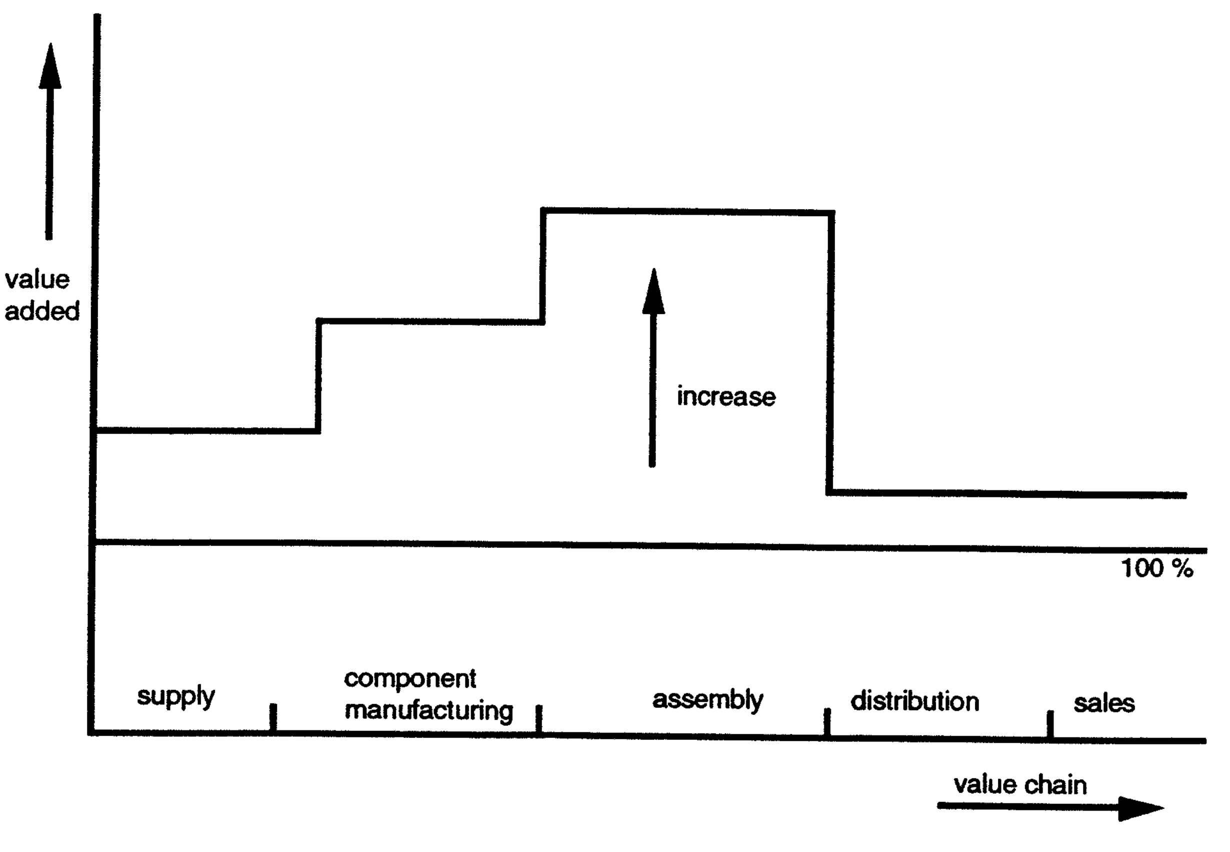

Figure 4 **Effect of Environmental Costing on Value Added**

For the same reason, it is difficult to estimate the situation in assembly. There will be a considerable increase in the costs of assembly, because this is the phase where the costs of reuse or disassembly will probably be allocated in most cases.

Thus, figure 4 gives additional insight into the nature of cost changes to be expected, but it does not change the main trends. These trends have been discussed above and will be summarized now:

- Competition in the European Community will be globalized.

- Product life-cyles will be shortened, even if the life of individual consumer goods will be prolonged.

- The added value in physical transformation is declining. Its marginal costs are sometimes almost equal to zero.

- Sales and manufacturing will be re-integrated, either by direct marketing, or through customer-driven production.

- The object of study ("The Manufacturing System") will be the total value chain, rather than the factory.

In fact we will go further. We believe the manufacturing system must now be seen in the context of the value chain. We term this the extended enterprise. If the challenge was to realize integration for the individual factory, the challenge now is to facilitate inter-enterprise integration across the value chain.

2.2 Inter-Enterprise Integration

Inter-enterprise integration encompasses the compression of "concept to customer" leadtime, working with just in time supply chains and logistic support throughout the product life. Against a *background of accelerating specialization and the visual disintegration of previously integrated businesses*, these trends drive the requirements for elements of integration such as electronic data interchange to new levels of complexity.

Keen (4) uses the terms "Reach" and "Range". Reach is the extent to which one can interact with other communication nodes - in the limit it becomes anyone, anywhere. Range defines the information types that can be supported from simple messaging between identical platforms to any computer generated data between any operating platforms (figure 5). The mapping of a company onto the range/reach chart gives a good indication of its scope for innovative business improvement through the use of integration technologies (figure 6). Classically high reach/range has been recognised as valuable but has been only available in specialist applications.

Some industry sectors have invested extensively in providing themselves with an industry specific capability. This expensive option is well illustrated by the automotive industry. In the manufacturing arena pan national competitive edge can be provided by access to creative information processing centres such as specialist design or manufacturing houses. The evolution of such systems is already apparent in niche product areas; the European Airbus, Tornado, the European Fighter Aircraft (EFA) and NH-90 Helicopter projects are good examples which typically handle 100,000 parts per aircraft. This technology will rapidly become appropriate, affordable and desirable for a broad spread of business enterprises as the dramatically declining information technology to labour cost ratio is maintained. Even the communications costs may be insignificant.

On a futuristic note; in *2061 Odyssey Three*, Arthur C. Clarke notes that the historic decision to eliminate all differential charges between local and long distance telephone calls on 31 December 2000 had significant sociological impact. The same is true for manufacturing organizations. *In fact the challenge of the integrated enterprise is not really a technical one, far more a challenge to management.* Power via conventional hierarchy is seriously weakened by the flat structure of the inter-enterprise environment.

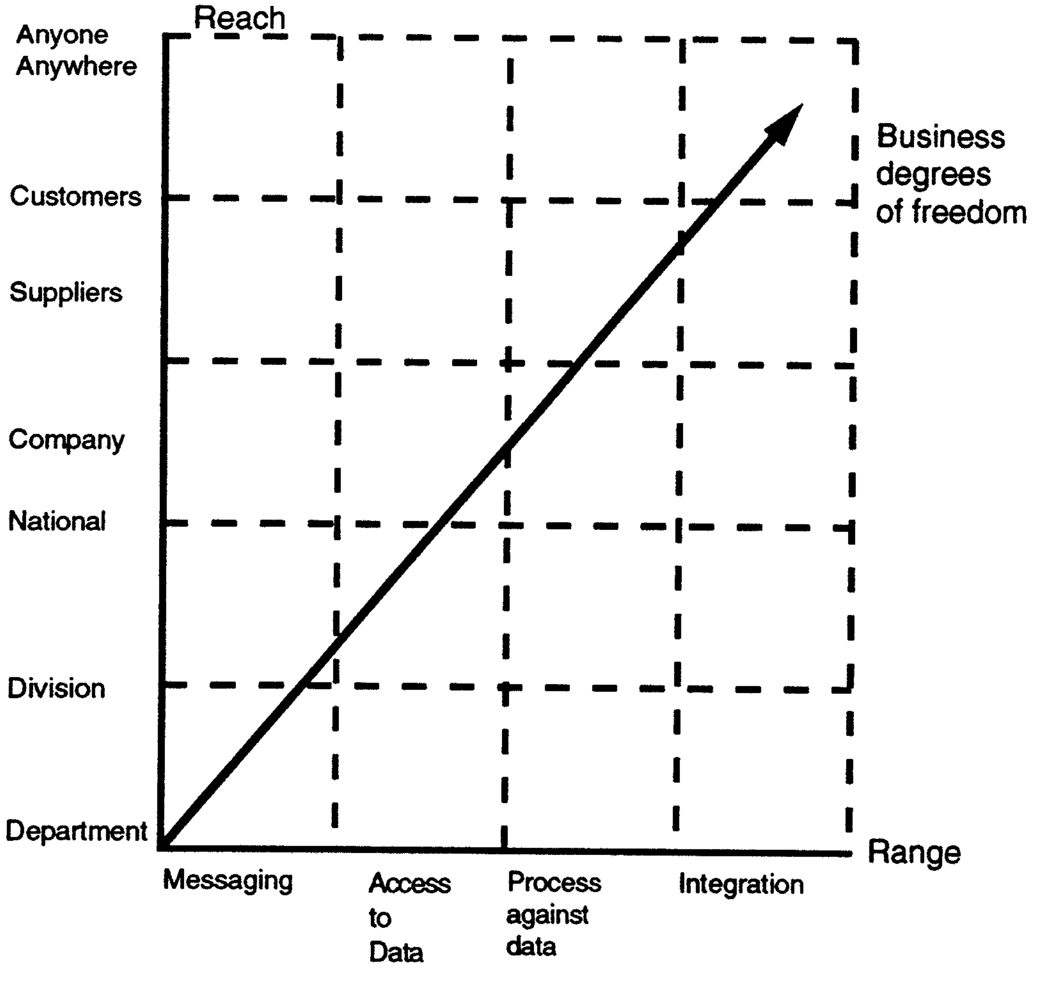

Figure 5 Business and Technology Integration

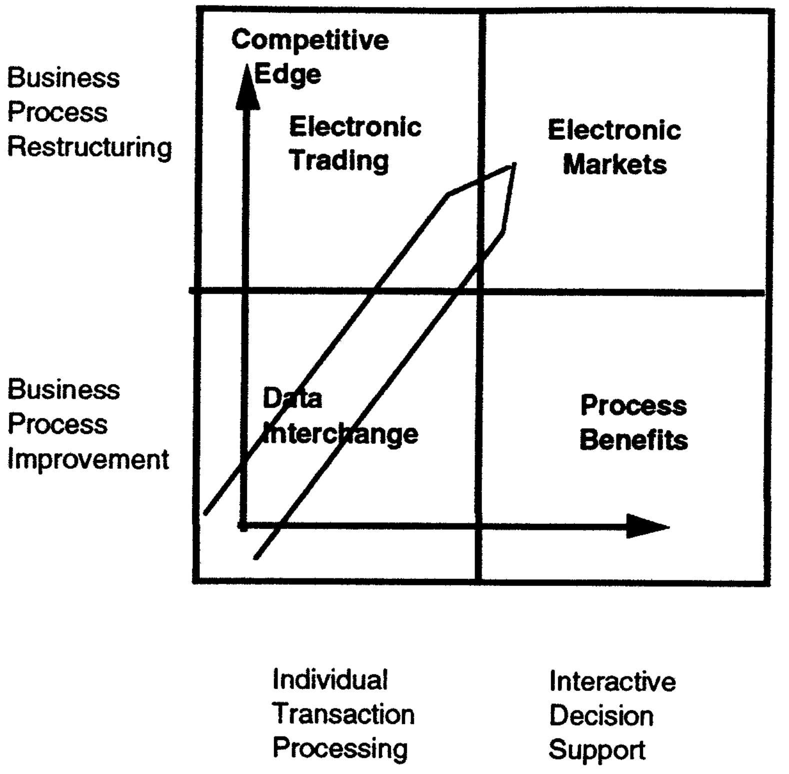

Figure 6 Scope for Business Improvement through Integration

This management challenge is a deviation from a tradition in information technology which views standards, architectures and even non-technical standards for business interchange as purely technical issues. *The reality is that businesses require electronic alliances to create value adding partnerships. It is no longer possible or even desirable to embrace world class capability in all the key functional areas wholly within the organization. Class leading competitiveness flourishes in an environment of dependency and interdependency with other providers of components, services, ideas. Inter-enterprise integration offers this capability.*

The United States Department of Defense initiative CALS - Computer-aided Acquisition and Logistics Support - will impact many European companies. It is likely that, together with the European initiatives, this will influence the standards and the pace for inter organization technical communication. The market place to which manufacturing businesses, business integration researchers, their teaching and their facilities must respond includes:-

- Business processes which cross enterprise boundaries to interface with functional areas in *other* companies:
  - Product design and definition
  - Manufacturing process definition
  - Manufacturing facilities

- Supplier/customer integration (people and processes) through interchange of commercial/technical data.

- Ability to function effectively as links for information and product in unbuffered supply/distribution chains.

The ability to integrate the activities of a number of entities to produce and sell manufactured products profitably will depend on the relationship of these entities and the communication that passes between them (figure 7).

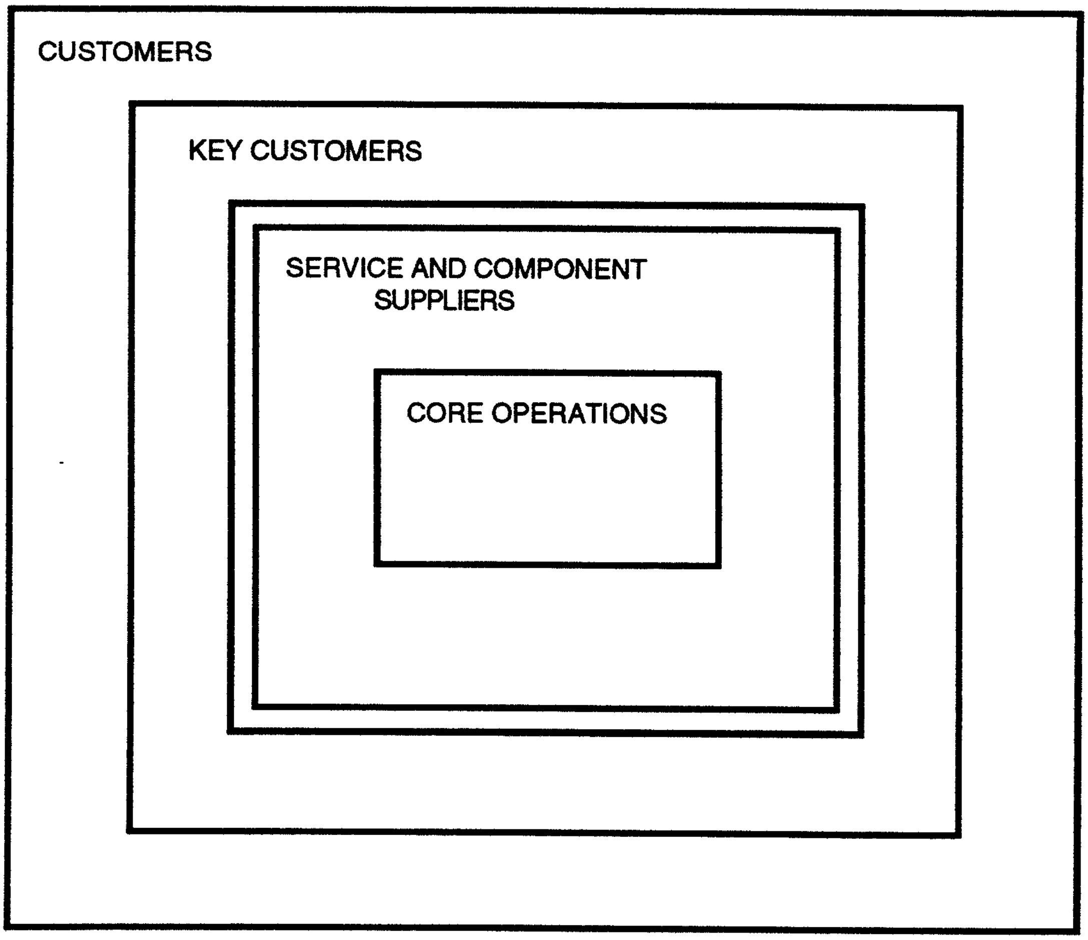

Figure 7 The Extended Enterprise

We are accustomed to thinking about this in the context of a single enterprise with different departments, Sales, Design, Engineering, Manufacturing, Distribution etc. *However, within a large market-place, entities from many different enterprises, or entities which in themselves are nominally independent enterprises, relate via a single product to produce a designed result.* An example might be a merchandising entity recognising a business opportunity and requesting :-

- a design entity to design it;
- a manufacturing entity to build it;
- a distribution entity to distribute it and;
- a marketing entity to sell it.

The implication of such an example is that all the entities can be considered as "flexible" or "programmable" within their expertise envelope.

2.3 Issues in the Extended Enterprise

In the context of the extended enterprise and the need for inter-enterprise integration, it seems to us that there are five issues which should be emphasised.

- Firstly there is the fact of *reduced product life cycles* and the consequences in terms of flexibility in the manufacturing capability.
- Secondly there is the issue of *time based competition* and the associated need to reduce the time to market for new products.
- Thirdly there is the necessity of taking *a total product life cycle view* due to the heightened awareness of environmental problems.
- Fourthly there is the challenge of *creating organisations* and systems which attract *high quality people* and make full use of their capabilities.
- Finally there is the problem for the individual manufacturer of developing a *manufacturing strategy* which is appropriate to the business environment and which takes account of the position of the manufacturing facility in the value chain.

We will now review each of these issues in more detail.

2.3.1 Product Life Cycle

The notion of stability in manufacture with standard products built on standard systems for extended periods can now be viewed in context: a brief, and exceptional time which rose to prominence in the immediate post war period, chiefly in the USA. Stability is not normal. The natural environment encourages variety, short life, niche habitats, customisation. This was the case in manufacturing before the mid part of this century. Special circumstances and technological constraints changed the basis of competition in many markets between 1940/1960. The 'natural' order has now reimposed itself. Customer awareness of technological development on a global scale, electronic communications, close coupling of the customer to the manufacturing source have all led to reduced product life cycle. Over riding this is the competitive position faced by all manufacturers who have to satisfy changing customer preferences.

In the late seventies and early eighties the concept of flexible manufacturing systems was widely publicised. The system which resulted serviced an environment where product life had fallen below manufacturing facilities life. It was becoming increasingly difficult to justify dedicated single product automated manufacturing facilities.

Flexible manufacturing systems exhibited a relatively high degree of *Transient Flexibility* compared to hard automation. Many systems had the ability to process more than one product type or family. This *State Flexibility* must not be confused with the emerging requirements imposed on manufacturing facility provision by current developments in product life cycles. *Pure one-of-a-kind engineer and manufacture to order remains a small market opportunity but custom build of options to order on a common product platform is a rapid growth area.* It potentially embraces clothing and consumer durables as well as regular customised products. For standard products short life is coupled with the requirement to bring high volumes of newly specified, fully conforming product to market near instantaneously with the release of specification to production.

Engineered products have an increasing proportion of their added value provided by software or design features. The reproduction costs of say a software derived feature are not volume sensitive. But market price is highly time sensitive. So viability in the face of high development costs requires high volume capability at start up. The demand curves of product introduction, maturation, decline, increasingly resemble a square wave form.

Environmental concerns raise the rate of new product and process introduction to cope with legislation. Increasingly we may experience customer rejection of non recyclable/non upgradable products. *We will see short manufacturing product life coupled with extended field life and return to plant for upgrading, perhaps reprogramming.*

The effect of all these developments is to raise the requirement for flexibility in manufacturing capability to new heights, and to impose a high degree of uncertainty into all aspects of the manufacturing process. These requirements can not be met by incremental developments to existing research directions.

The required flexibility will require *enterprise agility and access to external resources through the extended enterprise.* This will place special requirements for *plug compatible process planning* systems. Physical manufacturing plant and its control systems - both process control and production control, will have to be reconfigured as an ongoing activity. There will be little opportunity for learning by error. The manufacturing organisation will have to adopt the style of the *learning organisation.* Training systems will be an integral part of work place fitness. This rate of change will pose problems for performance measurements and costing systems. New metrics will be needed. Similarly manufacturing strategy and investment decisions will be rapidly degraded by time. Support tools and near real time reassessment will be a requirement.

Metrics are important. Metrics or measures of performance provide milestones against which performance can be evaluated. However measures of performance also serve to influence, oftentimes to direct behaviour. The measures of performance must therefore reflect well the objectives of the manufacturing system. Frequently, in the past certainly, a preoccupation with one measure, namely cost was often to the detriment of others such as quality, responsiveness etc.

2.3.2 Product Concept to Manufacture - Time to Market*

Recent findings have highlighted the relative success of companies who successfully reduce Time to Market.

	Winners	Losers
Automobile Design	3 yrs	7 yrs
Computer Design	9 mths	4 yrs
Retail Clothing	36 hrs	6 weeks

Best practice in the field stretches the advantage of time based competition still further. In 1985 the Japanese automobile industry worked at 42 months for the new product introduction cycle. Currently they are planning for 24 months and substantially increasing the number of new products being introduced. Many European and US successes have been realised through rapid product introduction programmes. For example, in the process industry, Proctor and Gamble have reduced their Time to Market for new products by 50% since 1987.

The most extreme cases arise from military products. Traditionally military products demonstrate extended product development time. Yet paradoxically the industry has exhibited 'impossible' performance. A recent European example is the design, development, implementation and staff training to allow in flight refuelling capability on 20+ year old aircraft. This enabled the British to service their troops in a dispute with Argentina. The 'Time to Market' this complex system was less than 2 weeks. More recently in the Gulf War; a new type of bomb was required to penetrate command posts encased in concrete and buried 30m underground. Texas Instruments used a team of 18 engineers to complete in 1 week, complex wind tunnel and simulation tests normally allocated 18-14 months. The time between customer request and delivery of product in the field was 1 month. Normal time is 2.5 years.

These military examples are undertaken without regard to cost - in fact usually ahead of cost authorisation. Yet the net effect is better products in greatly reduced time at substantially less cost than the normal development process. The accelerated Time to Market (TTM) process is not risk free. In Japan only 1 in 4 products launched on the domestic market are developed for sales outside Japan. Yet fast TTM does not automatically lead to expensive product development programmes. Many practitioners report reduced costs and better products.

Clark (reported in reference 9) argues that lean product development techniques *simultaneously reduce the effort and time involved in manufacturing*. Lean product development techniques based on project leadership, teamwork, good communications and simultaneous development/engineering, have had tremendous consequences in the auto industry. Clark et al (5) illustrate the impact of lean design* , as practiced

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* For a summary overview of the issues raised here, see Appendix 4.

* In Appendix 1 we present a short overview of Lean Production.

by Japanese auto producers compared to their European and American competitors.

The strategic impact of compressed TTM on manufacturing organisations is far reaching. Largest profits are available to those early in the market. In 1987 Clark & Fujimot (5) showed that each 1 day delay in introducing a new mid size car on the international market represents at least 1m ECU in lost profits. A separate study found that, amongst leading companies, operating in competitive markets, a 50% overspend on product development results in a 3-4% drop in life cycle profits. A 6 month delay in TTM causes a 32% drop in profit.

The relationship between the price that the market will bear and time is heavily skewed in favour of early availability in the market. Heavy discounting of products only a few months old is common. So late producers may never have a profit harvesting phase. Opportunities do exist for suppliers choosing to come late into the market. These opportunities arise from the increasingly mechatronic nature of many products. The high ratio of added value through design means that replication of developed products bears a very low additional cost. Late into market producers can capitalise on this if they can rapidly reproduce products developed by others. Either way, for new product producers or 'clone' product producers, TTM is crucial. The fast producer can proliferate variants, create market segmentation and generate profit potential. Fast to market producers are in fact lower risk producers. They have multiple opportunity for interactive, low risk, developments all of which are customer driven. Their fast processes are usually highly controlled, cost effective processes.

The emerging Time to Market challenge can be likened to an earlier manufacturing systems challenge - material control. *In the past material control was crucial to manufacturing success. Now manufacturing is as much an idea system as a material processing system. The generation, communication and application of ideas and their application in products is the core of fast Time to Market. The manufacturing system must be open to idea input: hence increasing reliance on the extended enterprise including customer input.*

Communications and empowering of individuals will shift the demands on both organisation structure and enterprise to interaction. Extra life cycle values and requirements for design integrity backed by deterministic process in manufacture will demand a new generation of concurrent engineering support tools.

2.3.3 Total Product Life Cycle View*

It is an interesting paradox, referred to earlier and repeated here that we are likely to see short manufacturing product life coupled with extended field life and possible return to plant for upgrading, perhaps reprogramming. There is a definite pressure on the manufacturing

* For a summary overview of the issues raised here, see Appendix 3.

system to take responsibility for the total life cycle of a product, including the environmental effects and the costs of disassembly, disposal, or refurbishment. The ultimate aim is complete reuse of materials in order to obtain manufacturing systems which are neutral with respect to the environment.

Issues to be taken into account here are:

- Legislation with respect to environmental side effects.

- Environmental costing.

- Lack of virgin materials in the long run.

- Consumer's rejection of products where recycling has not been made possible.

The current response to the above challenges, is to focus primarily on the product development process. Many product development departments at different companies perform studies for multi-life cycle usage of components. These studies are combined with manufacturing engineering studies for the development of production processes where harmless end-of-life disposal, disassembly or refurbishment is facilitated.

In combination with these studies, new forms of economic and legal trading conditions must be investigated, such as:

- Lease of commodities in place of purchase, i.e. the ownership rests with the producer.

- Upgrade of modules of an installed base in such a way that modules are recycled and reused, whereby the installed product is continuously refurbished. Such a policy goes together with new methods of payment for products during the period of product-usage by customers.

- Tracing and tracking of individual products which are difficult to identify, such as fresh food or household commodities.

The challenge lies in creating manufacturing systems which do not affect the environment; and the current response lies in charging the engineers primarily with finding solutions. This situation creates two difficulties, an immediate difficulty and a more fundamental difficulty. The immediate difficulty is that the product and process development engineers do not have a design methodology (or even experience) available for satisfying these new constraints. Quite often, basic information about environmental impact is simply not available. A more fundamental difficulty, however, lies in the fact that almost every function in society has to change its paradigm. Not only engineers, but also lawyers, accountants, politicians, investors, consumers will be confronted with the consequences of the requirements for environmentally benign manufacturing systems. This shift of paradigm of nearly all parties involved in the business, increases the uncertainty of the engineers in charge of finding better technological solutions.We believe that this shift of paradigm is in itself too complicated to be treated here in the same way as the other issues of this report. We suggest, that a separate study is devoted to this point.

Despite our advice to devote a further study to the shift of paradigm and its consequences, one solution for many companies is clear. Enterprises involved in the production of physical goods will need access to very well educated people to solve the problems of environmentally benign manufacturing. This has a number of consequences for these enterprises, but also for the society as a whole. The enterprises should be aware of the fact that excellent employees are the ultimate source of global competitiveness, in the long run. This means that manufacturing should provide excellent working conditions and abandon its image of dirt, repetition, and anonymity. High quality jobs should be provided, in a clean, attractive, and safe setting, challenging the employees with a high rate of change in technology. Society as a whole should provide education programs in technology which make technology attractive to young people. These programs should enable students to become product- and process-development engineers* for whom continuing education in other fields (including law and economics) is completely natural.

2.3.4 High Quality Organisations and People

High quality organisations and people constitute the fourth key-element in the future of our manufacturing system. To attract high quality organisations and people, industry has to fight several battles.

First of all, industrial work has a connotation of being laborious and tedious. Industry and education should cooperate to improve this image. A career in technology should be perceived as challenging, rewarding, and innovative. Societal welfare is largely due to manufacturing technology, and in particular its' output.

Second, it is unlikely that inter-enterprise integration can be obtained without a shift of paradigm in the work organisation itself. It seems that the industry will move towards the management of knowledge, rather than the management of physical assets. The hierarchical paradigm of organizations with its focus on vertical command chains will probably be replaced by a *networking* paradigm with focus on horizontal communication.

Learning is another aspect of future organizational forms. In earlier days, Computer Integrated Manufacturing was assumed to yield factories which would no longer employ humans. However, humans have never been absent in manufacturing. Improvement in manufacturing follows learning curves, and these learning curves stop if completely automated machinery comes into play.

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* See Appendix 5 for one view of the role of the manufacturing engineer in the 21st century.

Consequently, we should think of manufacturing as a system of continuous change and improvement, rather than as a machine which repeats itself. Future manufacturing should become a *learning organization (See Senge (12)).*

A learning organization is not the same as a collection of learning individuals. An organization may easily fail to reuse its knowledge, although the individuals do learn. Of course, individual learning is a necessary condition for a learning organization. However, organizational learning is primarily concerned with cooperation. As such, learning organizations will be suitable for inter-enterprise integration.

2.3.5 Developing a Manufacturing Strategy

The 1990 International Manufacturing Futures Survey identified manufacturing strategy determination as an important topic for manufacturing companies. Based on a survey of manufacturing enterprises in three regions, namely Japan, the United States and Europe this report (see reference 11) concluded that :-

> "..the factories of the future in each region are all focused on the development of organizations in which manufacturing strategy is tightly linked with the business strategy. All three regions report a high emphasis on the linkage between manufacturing's functional strategy and the overall business direction. This result signifies recognition of the manufacturing function's strategic importance in an increasingly competitive global marketplace".

This recognition of the importance of manufacturing strategy determination is not new. For example Skinner argued that :-

> ".. 40% of any manufacturing based competitive advantage comes from the long term planning of the manufacturing strategy, involving decisions pertaining to the number, size, location and capacity of facilities and the basic approach to materials and workforce management. Another 40% comes from major changes in equipment and process technology, while the remaining 20% emanates from narrow operational cost - reduction parameters for productivity. *In effect 80% of the advantage is achieved by the determination and implementation of good strategic decisions.* Unfortunately very little focused research has gone into ensuring that methodologies, frameworks and models are available to assist managers to make good strategic decisions".

The Society of Manufacturing Engineers (6) in the US also argue for increased emphasis on the development of manufacturing strategy. They argue that:-

> "Manufacturing of future products will differ dramatically from today. How raw materials are converted and transformed will become a more strategic decision. This decision will become more complicated in terms of what to make or where to buy in a world that is becoming a huge, single economy....... Strategic alliances between

companies, co-operative production agreements, advanced processing technologies and their justification, and numerous other factors will be added to an increasingly complex manufacturing equation".

In fact the SME go further and suggest that the manufacturing engineer of the future will have multiple roles, namely that of technical specialist, operations integration and *manufacturing strategist.*

It seems to us that in the context of the extended enterprise, strategic manufacturing decisions will be difficult to make. Furthermore the costs of poor decisions will be extremely high.

3 Proposed Research Topics

In section 2 we argued strongly that the object of study in this report is the *extended enterprise*, and that the challenge to manufacturing today is to facilitate inter-enterprise integration across the total value chain. Based on this concept of a dependent enterprise operating within an integrated value chain we now identify five themes where community support for research and development is appropriate. The five themes are:-

- Inter-Enterprise Integration,
- Concurrent Engineering,
- Organisational Learning,
- Investment Appraisal for the Extended Enterprise,
- Manufacturing Information Systems,

For each research theme we identify a number of research and development opportunities. We categorize the opportunities in terms of short term, medium term and long term. By short term we mean up to three years, medium term up to five years and long term up to ten years. We further indicate whether these research opportunities should be taken up by research consortia which are industry led or research institute led. We assume that the research consortia will be constituted in a similar manner to existing ESPRIT and BRITE-EURAM consortia. Further we define two areas where special action at community level is appropriate.

3.1 Inter-Enterprise Integration

The extended enterprise is an expression of the market driven requirement to embrace external resources in the enterprise without owning them. Core business focus is the route to excellence but product/service delivery requires the amalgam of multiple world class capability. Changing markets require fluctuating mixes of resources. The extended enterprise, which can be likened to the ultimate in customisable, reconfigurable manufacturing resource, is the goal. The process is applicable even within large organisations as they increasingly metamorphasise into umbrellas for smaller business units/focused factories. The concept is central to the USA view (See 21st Century Manufacturing Enterprise Strategy (7)).

The operation of the extended enterprise requires take up of communications and database technologies which are near to the current state of the art. *However the main challenge is organisational rather than technological.* Concerns experienced in the flatter organisations developed in Computer Integrated Manufacturing type business enterprises such as trust, credibility and project management assume high profile in the extended enterprise.

Research and Development Opportunities

- Methodology for determining and supporting the information processes in the extended enterprise. This work will build on process modelling but extend beyond the traditional single business boundary. It will provide the basis for effective extended enterprise operation by defining what information should be communicated and when and where decisions must be made. *[Short Term, Industry Led]*.

- Pre Qualification of Partners. The extended enterprise is a volatile environment, partners will regularly join and rejoin a new 'consortium' of enterprises. Pre qualification tools to determine entry level and acceptability are required. These need to embrace physical process and knowledge work capability. *[Medium Term, Industry Led]*.

- Architecture for engineering partnership, an abstract representation of an extended enterprise engineering partnership and associated systems architecture. This would support concurrent engineering across the extended enterprise and, through specification to participating partners, enable realisation of short Time to Market in this environment. *[Medium Term, Industry Led]*.

- Business and legal framework to facilitate the emergence of transient integrated enterprises. Issues to be researched, understood and articulated include product liability responsibility across the value chain, recyclability issues, ownership of individual enterprises and products, intellectual property rights etc. *[Long Term, Multidisciplinary Research Institutes]*.

- Development/demonstration platform, University/Research Institute pan European demonstration facility. The technology offers scope for an extended facility collectively resident in certain academic institutes and accessible for evaluation from multiple points in the Community. *[Short Term, Research Institutes]*.

3.2 Concurrent Engineering (CE)

The UK CE industrial forum has defined Concurrent Engineering as 'delivery of better, cheaper faster products to market by a lean way of working using multidisciplinary teams, right first time methods and parallel processing activities to continuously consider all constraints'. CE must adapt a true life cycle view. This implies consideration of issues such as maintainability, upgradability, recycleability, use of environmentally benign processes, reuse of scarce materials etc. at the earliest stages of design.

Tools in CE can be broadly classified under three categories; *management* based, encompassing such things as team working, *project management*, and *formal methods* of geometric manipulation of drawings and models. *There has been a focus on tools and techniques and a lack of research into how, when and in what order to implement them*. The extended enterprise poses special challenges for the realisation of Concurrent Engineering.

Research and Development Opportunities

- New organizational structures for the organization of concurrent engineering. The distribution of tasks to various members of a product development team is a very important issue. A related question is how to create cross-functional task teams in such a way that:
  - traditional accounting procedures do not hamper teamwork;
  - the reward system can be based on an individual's performance in projects rather than in the functional organization;
  - reuse of experience is guaranteed;
  - learning is part of the task assignment.

  In general, the transition from a traditional hierarchical organization to a networking organisation is especially important for concurrent engineering. *[Short Term, Industry Led].*

- Self analysis of design performance. This includes methodologies and systems which prompt the user for information on the design process, map this against established benchmarks and offer specific advice of action, consequences, problems, solutions. *[Medium Term, Industry and Research Institutes].*

- Multi function design team support, for use in managing, setting up and participating in extended enterprise design teams. *[Medium Term, Industry Led].*

- IT tools for the large team environment. Classical CE work has envisaged the compact team. Large multi site, multi sub system design problems require new infrastructure. Effective operations requires attention to the design process and information management and presentation to minimize information overload. Mutimedia may be effective here. *[Medium Term, Research Institute Led].*

- Training Systems for use in extended enterprise rapid configuring teams. Multimedia also offers significant potential benefits here. *[Short Term, Industry Led].*

- Development of a Negotiation Environment in Concurrent Engineering. This environment will facilitate distributed design activity and will manage the interaction between designers by facilitating appropriate local action. *[Long Term, Industry and Research Institutes].*

- The development of design methodologies to incorporate a *true* product life cycle view at the earliest (i.e. conceptual) stage in design. *[Long Term, Industry and Research Institutes].*

3.3 Organisational Learning

Competitive advantage is provided by the ability to learn faster than ones rivals. In an environment of uncertainty mere training does not equip staff with the necessary manufacturing problem solving capacity either in individual or collaborative mode. The central idea of organisational learning is that organisational capability to deal with changes and uncertainty can be fostered, its formal basis defined and best practice replicated and augmented. So in the Learning Organisation, 'organisations', including individuals, can learn from experience to recognise problems and either solve them or initiate successful solution methodologies. In many ways the Learning Organisation adopts the characteristics of a living system. The key difficulties with the concept are what constitutes learning and how to embody it and how to define problems. It is inappropriate to adopt human learning processes and theories directly as a metaphor for the learning which occurs in organisations.

Research and Development Opportunities

- Formation of a learning process designed to maintain an organisation's competitive advantage, enabling it to selectively customise and develop its own emergent manufacturing techniques. *[Short Term, Industry Led].*

- Development of a process for managing learning strategically and tactically within an organisation, capitalising on determining the sources of success and failure and hence identifying best practice. *[Medium Term, Research Institute Led].*

- Development of a programme of action-learning research in which the process under development in the previous item is implemented in up to five organisations over a 2-year period. This will give the host organisations a chance to be at the leading edge of organisational development through sharing the necessary teaming, problem-solving and learning skills to implement a strategic learning approach within their organisations. *[Medium Term, Industry Led].*

- The definition of a focused research agenda leading to projects in the wide organisational learning domain by a consortium of partners. Supported by shared secretariat support for workshops to share learning from member organisations, presenting papers, hosting internal conferences, developing methodologies for shared use, embodying learning from the consortium. *[Initiated Short Term but Running Long Term, Research Institute Led].*

3.4 Investment Appraisal for the Extended Enterprise

Decision support aid in investment planning offers help to managers in making effective and defensible decisions about organisation and technology. It concentrates on value rather than mechanism: on why to change manufacturing systems or establish new ones rather than how to do it.

Economic models for manufacturing organisation assume that the two basic forms of combination are markets and hierarchies. In the Extended Enterprise this analysis needs to be revised. Extended enterprises retain the disciplines of the market yet establish a relationship between supplier and customer that outlasts and goes far beyond single commercial transactions.

Investment Appraisal includes a number of related areas of work. The first concerns the explanation of various kinds of manufacturing organisation: why supply chains should be integrated within the umbrella of a single firm, how the concentration of suppliers and buyers in a particular market can be explained, where economies and diseconomies of scale lie, and so on. A second area of work covers the development of decision making tools such as scoring and finance models. These are sometimes derived from theories about how people make choices, and sometimes rest simply on the basis of their intuitive appeal. The main difficulty is that the parameters are difficult to estimate with any degree of objectivity. A further area of interest is the analysis of the risk associated with new industrial technologies. Probabilistic models are the more traditional approach. In essence they capture the idea that the future will take one of a number of possible states, and that a decision maker will choose one of a number of alternative courses of action based on their anticipated payoffs in each of those states. Linguistic models substitute terms in natural language for both the probabilities of future states occurring and for the payoffs.

Research and Development Opportunities

- Rigourous methodology for predicting when and how extended enterprises should be established. This will lead to a prescription of how industrialists need to conduct their business in the resulting organisation. *[Medium Term, Industry Led].*

- Development of financial value estimating systems. Current financial value estimates are too simplistic and do not properly consider growth options. This is particularly significant in the Extended Enterprise. *[Medium Term, Industry Led].*

- Identification of investment opportunities. This is at least as important as evaluation of options. It is linked with strategy formulation and has been much neglected. *[Short Term, Industry Led].*

- Risk analysis. The organisation structure proposed requires better tools to assess the degree to which qualifications of costs and benefits is subject to error. Simple probabilities are less useful than methodologies which address how people react in the face of uncertainty and how they act to mitigate the effects of uncertainty. *[Long Term, Research Institute Led].*

- Value chain costing. The combination of environmental and society concerns relating to manufactured product life cycles and the extended enterprise is a new area. This is likely to have significant impact on the development of competitive and responsive extended enterprise operators. *[Long Term, Research Institute Led].*

- Integrated methodologies. Prescriptive and descriptive models which connect general themes such as economies of scope, environmental impact, with the search for new investment opportunities, with the metrics by which these opportunities are assessed, and the way in which uncertainty about these opportunities can be expressed and managed. *[Long Term, Research Institute Led].*

3.5 Manufacturing Information Systems

The extended enterprise manufacturing system requires channels that convey information from one system to another. Without these connections the gains in productivity and flexibility that we look for are compromised by mismatches and rigidities at their boundaries.

One form of this problem involves the integration of existing, proprietary applications that have been built on heterogeneous infrastructures: differing machines, operating systems and database management systems. We have to retrofit to relatively impenetrable human and technical systems the mechanisms that will make their operation cohesive in an extended enterprise environment. In particular we have to provide for product traceability and potential liability arising from environmental legislation and value chain costing.

Distributed database mechanisms offer a potential solution. By presenting the data on which applications work in a uniform, self-consistent way we can make sure they share the same view of the factory. Where the same data is stored in more than one of the local systems it should have the same meaning, if not an identical form, in all of them. The object transcription approach, avoids some of the intricacies of distributed databases. The movement of data from one local system to another takes place in complex objects of pre-defined content. Such schemes avoid having to reconcile the different data models and manipulation languages underlying the different applications.

Apart from data infrastructure the extended enterprise, extra enterprise teaming, and prosumer product configuration, require new information communication mechanisms.

Developments in communications technology such as mobile telephones, FAX, Electronic Mail, Video conference and even express delivery of conventional mail have been widely adopted. Advances in computer communications have been driven by the need to transfer data from one computer to another. Only Electronic Mail has attempted to exploit the capability to allow one computer user to communicate directly with another user. Multimedia is the combination of appropriate communications medium to best represent human readable information. It can be particularly useful to non specialist users. It allows customer input to the manufacturing system in a novel way. It allows remote site concurrent engineering teams to hold meaningful dialogue. It offers scope for bandwith effective communication of graphical information. It is near language independent.

The potential for multimedia as an extended enterprise user-to-user communications medium is largely unexplored. Most of the physical infrastructure required is being put in place. Telecommunications utilities are proceeding with the implementation of ISDN services, and there is a large base of existing users with demanding communications needs.

Research and Development Opportunities

- Alternative integration methods. Different business situations place differing demands on information channel cost, quality, volume, graphical and textural content. Methodologies appropriate to these environments need to be readily mapped to the need and the implications for business strategy. *[Medium Term, Industry Led].*

- Integrating remote applications. Methodologies to resolve inconsistent data meanings and structures across the extended enterprise. *[Medium Term, Research Institute Led].*

- Product traceability. The determination of a process to cost effectively allow environmentally sensitive product to be tracked in field. *[Medium Term, Industry Led].*

- Authoring tools for manufacturing multimedia messages. Currently comprehensive tools and author expertise are expected, and development time and cost are justified by having many receivers and an extended lifetime for every message. This is not appropriate for a communications application, where there may be one receiver and a short message lifetime. *[Medium Term, Research Institute Led].*

- Product description communication. Methodologies for cost effective transmission and control of appropriate graphical, pictorial and textural data to support the business and product development process. This would allow best use of language independent moving image technology. *[Long Term, Research Institute Led].*

3.6 Special Actions

There are two areas where special action at European level is needed, viz the area of curriculum development for engineering (specifically manufacturing engineering) in the extended enterprise, and the issue of manufacturing enterprises operating in peripheral regions of the Community.

Curriculum Development

Many universities in Europe have faculties for mechanical engineering, electrical engineering, chemical engineering, civil engineering etc. However, manufacturing as a discipline is underdeveloped, and there is no established body in Europe which develops curricula, considering manufacturing as a system. In the USA there exists an accrediation board for industrial engineering, but the field of industrial engineering has a much narrower scope than required. Although at several places in Europe various universities have developed courses at batchelors level, at masters level, or beyond, there is no general understanding of the real meaning of (and need for) manufacturing, including human aspects, environmental impact, economic considerations, and global competition.
Secondly, engineering students are usually well trained in a particular discipline, but they have no training in integrating several disciplines for the design of families of industrial products. The notion of concurrent engineering as an important part of education is seldom present in today's curricula.

We advocate an action which stimulates the development of curricula, and the establishment of accreditation boards in Europe both for manufacturing as a discipline and for concurrent engineering. We believe that high quality broadly trained manufacturing engineers are critical to success in the extended enterprise environment .

Peripheral Regions

We are concerned that the development of inter-enterprise integration may lead to a situation where manufacturing enterprises located in peripheral regions of the Community may be placed at a disadvantage. Advanced telecommunication and computing systems will certainly facilitate information flow within the Community, but geography will continue to place some enterprises at a disadvantage in terms of rapid goods flow. The trend towards inter-enterprise integration may well accentuate this disadvantage.

Action is appropriate at Community levels to better understand this potential problem and to suggest remedial action, if such is considered desirable.

4 Conclusions

Manufacturing systems are subject to tremendous pressures in terms of global competition, developing environmentally benign production processes and products and the development of new forms of business organization. It is no longer feasible to look in isolation at the manufacturing system. The manufacturing system must be seen in the context of the total business and the linkages of the business back through the supplier chain and forward into the customer chain. The challenge for the future is to consider the extended enterprise and facilitate inter-enterprise integration across the value chain.

In the context of the extended enterprise and the need for inter-enterprise integration, there are five major topics which need to be considered, namely:-

- The fact of *reduced product life cycles* and the consequences in terms of flexibility in the manufacturing capability.
- The issue of *time based competition* and the associated need to reduce the time to market for new products.
- The necessity of taking *a total product life cycle view* due to the heightened awareness of environmental problems.
- The challenge of *creating organisations* and systems which atttract *high quality people* and make full use of their capabilities.
- Finally there is the problem for the individual manufacturer of developing a *manufacturing strategy* which is appropriate to the business environment and which takes account of the position of the manufacturing facility in the value chain.

A major research programme, addressing the issue of inter-enterprise integration would directly impact European competitiveness and allow Europe to take the lead in 21st Century manufacturing. Further special actions in the areas of manufacturing systems curriculum development and the special needs of peripheral regions are suggested.

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Appendix 1.

What is Lean Production?*

The term "Lean Production" was coined by the research team involved in the IMVP (International Motor Vehicle Programme) research programme (see Womack et al).

They described lean production, by contrasting it with craft production and mass production. The following extract from Womack et al summarizes the basic ideas:

"What is lean production? Perhaps the best way to describe this innovative production system is to contrast it with craft production and mass production, the two other methods humans have devised to make things.

The craft producer uses highly skilled workers and simple but flexible tools to make exactly what the consumer asks for - on item at a time. Custom furniture, works of decorative art, and a few exotic sports cars provide current-day examples. We all love the idea of craft production, but the problem with it is obvious: Goods produced by the craft method - as automobiles once were exclusively - cost too much for most of us to afford. So mass production was developed at the beginning of the twentieth century as an alternative.

The mass-producer uses narrowly skilled professionals to design products made by unskilled or semi-skilled workers tending expensive, single-purpose machines. These churn out standardized products in very high volume. Because the machinery costs so much and is so intolerant of disruption, the mass-producer adds many buffers - extra supplies, extra worker, and extra space - to assure smooth production. Because changing over to a new product costs even more, the mass-producer keeps standard designs in production for as long as possible. The result: The consumer gets lower costs but at the expense of variety and by means of work methods that most employees find boring and dispiriting.

The lean producer by contrast, combines the advantages of craft and mass production, while avoiding the high cost of the former and the rigidity of the latter. Toward this end, lean producers employ teams of multiskilled workers at all levels of the organization and use highly flexible, increasingly automated machines to produce volumes of products in enormous variety".

Womack et al claim that the origins of Lean Production go back to the early 1950s, when Toyota concluded that mass production was inappropriate to Japan and set about developing an alternative approach. This alternative approach sought to make a greater variety of vehicles as demanded by the Japanese market, focused on reducing set up and changeover times at individual processes, developed new human resources ideas and quality ideas, and developed sophisticated supply chains to supply component and

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* Summary from "The Machine that Changed the World" by Womack et al (9).

sub-assemblies to the plants. Further these sophisticated supply chains were duplicated at the distribution and customer end, where a network of distributors and dealers was established. The dealer became part of the production system as Toyota gradually stopped building cars in advance for unknown buyers and slowly converted to a build to order system in which the dealer was the first step in the Kanban system, actually sending orders for presold cars to the factory for delivery to specific customers in two to three weeks.

The elements in Lean Production, according to Womack et al are:-

- Lean Manufacturing;
- Lean Design;
- Coordination of the Supply Chain;
- Dealing with Customers;
- Lean Management.

Lean Supply Chains

The Japanese supply chain is based on a small number of key suppliers, sometimes called first tier suppliers who in turn have a team of so called second-tier suppliers. These second tier suppliers in turn engage subcontractors in what becomes a supply pyramid. There are very close relationships between each link in the chain and it's lower level suppliers - design engineers are engaged early in the design process of the customer company. In the auto industry for example, the first tier suppliers have full responsibility for component systems and subassemblies that perform to an agreed performance specification in the finished car. The suppliers development team, with support from resident design engineers from the auto manufacturer and the second tier suppliers conducts detailed development and engineering (see Womack et al p.147).

Clearly the supply chains and "supplier pyramids" require substantial sharing of proprietary information and costing, and volumes and production techniques. The relationships between the auto producer and the various tiers of suppliers are managed through regional supplier associations. Through these associations new techniques including SPC, CAD etc. are disseminated.

The extent of these supply chains can be gauged from the following figures. According to Womack et al Toyota Motor Company accounts for 27% of the total cost of the materials, tools and finished parts required to make a car. The equivalent figure for General Motors in the US is 70%.

It is clear that Lean Supply Chains completely redefine the role of the purchasing organization in the manufacturing firm. Whereas the traditional role of purchasing was to define alternative suppliers, negotiate lower prices and expedite delivery to meet demand, lean manufacture refocuses and greatly extends the role of the purchasing function. The new purchasing function must work to develop an extended organization or enterprise based on close collaboration within the supply chain. Essentially the purchasing function must seek to develop partnership relationship with a smaller number of suppliers who themselves form the first tier in a supply pyramid. In the context of the extended enterprise the purchasing department must move towards a role which is essentially that of external resource (i.e. supplier chain) management. This external resource management role supports the early involvement of suppliers in new product development and design, very close customer - supplier relationships in terms of the sharing of cost and technical information previously considered proprietary, the sharing of specialists etc.

The Customer Chains in Lean Production

According to Womack et al, the lean approach to dealing with customers is significantly different in concept from the mass-producers' concept.

Specifically:

> " First, the Japanese selling system is active, not passive; indeed the Japanese call it"aggressive selling". Rather than waiting at the dealership for customers attracted by advertising and publicly announced price cuts, such as factory rebates, the dealer's personnel periodically visit all households in the dealers service area. When sales lag, the sales force puts in more hours, and when sales lag to the point that the factory no longer has enough orders to sustain full output, production personnel can be transferred into the sales system. (The type of transfer occurred during Mazda's crisis in 1974 and, more recently at Subaru).
>
> Second, the lean producer treats the buyer - or owner - as an integral part of the production process. The elaborate data collection on owner preferences for new vehicles is fed systematically to development teams for new products, and the company goes to extraordinary lengths never to lose an owner once he or she is in the fold.
>
> Third, the system is lean. The whole distribution system contains three weeks' supply of finished units, most of which are already sold.
>
> The system that delivers this high level of service is also very different from a mass-production dealer system. The industry is very much more concentrated - there are only a total of 1,621 dealer firms in Japan, compared with some 16,300 dealer principals in the United States, a market two and a half times larger than Japan. Almost all Japanese dealers have multiple outlets and some of the largest easily match the megadealers found in the United States. In the same way as lean manufacturers only have a limited number of suppliers, they only work with a limited number of dealers, who all form an integrated part of their lean-manufacturing system".

Appendix 2.

Characteristics of a Customer Driven Manufacturing Process*

A true Customer Driven Manufacturing System

- Has a clearly articulated business and manufacturing strategy which defines the product set of the company and the market at which it is directed as well as the organization, technology, knowledge and skills required to meet the needs of that market.

- Is managed by a management team which seeks to achieve continuous improvement.

- Has defined a set of performance measures which serve to direct behaviour in accordance with the manufacturing strategy and customer needs as well as to measure performance.

- Has developed a reward system which is appropriate in terms of the performance measures defined earlier.

- Has developed excellent communications systems with customers and vendors. These external communications systems serve to develop partnership relations with customers and vendors.

- Has developed excellent internal communications systems in terms of product and indeed customer based teams with clearly defined roles and responsibilities. The emphasis on customer/product based teams is important in terms of defining customer and product responsibility rather than functional or process responsibility.

- Has developed flow based manufacturing systems which are customer demand driven rather than capacity driven.

- Has developed internal systems which capture learning and experience for reuse in subsequent orders.

- Recognises that well trained motivated people are critical to success and has developed policies to continuously retrain, reskill and motivate people.

- Has developed a manufacturing process which supports flexibility and responsiveness through very low levels of inventory, very low reject and scrap notes, high on time deliveries, very low set up times and very low lead times.

- Has developed a responsive organization in terms of its ability to reconfigure itself to meet external and internal demands.

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* Based on H.J. Stendel & P. Desruelle (8).

Manufacturing Product Life Cycle

External Pressures	Manufacturing Response	Difficulties Arising	Solution Domain
Technical developments in product & process.	Responsive manufacturing systems.	Manufacturing facilities investment planning.	Extended Enterprise.
Competitive pressure.	Extended Enterprise.	Rapid degradation of manufacturing strategy.	The Learning organisation.
Fashion/style changes.	Short life manufacturing facilities.	Scheduling of extended enterprise.	Enterprise agility.
Legislation changes on safety/environment.	Labour intensive manufacture.	Obsolete facilities.	Flexibility in manufacturing and machine systems.
Energy conservation needs.	Configuration/manufac-turing at customer site.	No opportunity for 'first-off' manufacturing.	Strategy determining tools.
Long product life in field.	Modularised manufacture.	Provision of spares for past products.	Modularised manufacturing control software.
Market rejection of non renewable, non recycleable/non refurbishable products.	Multiple build specification even for standard products.	Maintenance of quality.	Plug compatible process planning standards.
Raw material shortages.	Provide remanufacturing capability to upgrade field products	No stability in manufacturing costs performance.	Methodologies to incorporate environ-mental. issues.
Lower added value from physical process transformation.	Small lot, pipeless processing facilities.	Communication of build specification to manufacturing & assembly facility.	Cooperative 'self schedules' for manufacturing modules.
Availability of fast Time to Market capability.	In process reconfiguration.	Staff recruitment and training.	Decision support aids in investment planning.
Volatile economic climate.	Increased external sourcing of complete product modules.	Specification of manufacturing control software.	Multimedia application to support training.
		Product/process specification to remote enterprises.	Intelligent production images.
			Scalable architecture.
			Modular reconfiguration process hardware.
			Manufacturing metrics.

The System of Manufacturing: A Prospective Study

Time to Market - TTM

External Pressures	Manufacturing Response	Difficulties Arising	Solution Domain
Non linear market price/ time in market relationship.	Fast design system.	Need for management of ideas process.	Concurrent engineering design of product.
Small total market.	Control of product introduction process.	Fast move from new concept to proven, reliable product.	Computer support tools for design.
Competitor products.	Use of external to enterprise resources.	Product specification.	New organisational structures.
Time responsive competitor capability.	Use proven design process in fast mode.	No opportunity for prototype development/trials	Distributed team building methodologies.
Customer involvement in product specification.	Direct customer feedback to design and manufacturing.	Setting self management goals for teams.	Extended design/ manufacturing enterprise.
Global franchise concepts.	Adopt customer vision throughout the organisation.	Once launched product can be reproduced by competitors.	Intelligent product images.
Escalation in proportion of added value arising from design.	Multidisciplinary design teams embracing product and process.	Bureaucratic organisational structure.	Understanding of relationship between process parameters and product performance.
Flexible manufacturing capability.	Crisis teams.	Isolated specialist centres of knowledge.	Intelligent design system/architectures.
	Encourage idea generation.	Lack of visibility on capability of potential external partners.	Product/process simulators.
	Consider manufacturing constraints early.	Increased cost of running current design process in fast mode.	Plug compatible communications with external enterprises.
	Expand life cycle values considered in the design process.	New process = new benefits and new costs.	Pre-qualification methodology for external suppliers.

Appendix 5.

The role of "Manufacturing Engineer in the 21st Century" as seen by the Society of Manufacturing Engineers.

The SME argues that the future manufacturing engineer will have multiple roles. Specifically:-

"Manufacturing Engineers of the year 2000 will play alternate roles categorised as follows:-

- Operations Integrator;
- Manufacturing Strategist;
- Technical Specialist".

"Manufacturing engineers acting as operations integrators will possess a relatively equal balance of breath and depth skills ....

- They understand the product design process - but are not designers.
- They develop the strategic manufacturing plans and advise management on a course of action for their realization - but are not strategic planners.
- They plan and design manufacturing and warehousing facilities - but are not architects.
- They determine the type of equipment needed and negotiate with suppliers - but are not purchasing agents.
- They have extensive computer capability and program machinery and support equipment - but are not systems analysts.
- They are concerned about hazardous work environments, hazardous waste, and product liability - but are not lawyers.
- They understand value added concepts and collect, manipulate and furnish manufacturing data for use by finance - but are not accountants.
- They understand domestic and global business economics - but are not economists.
- They work closely with people at different levels of the organization. They understand the frailties of human beings who operate in high-tech environments - but are not psychologists.
- They respond to the marketing and sales organization, advising them on the never-ending variety of special products and deviations - but are not salespersons.

- They understand the importance of landed cost considering transportation and physical distribution - but are not logisticians.

- They develop and coordinate the entire manufacturing process from product design through after-sales service - they are the new manufacturing engineers in the role of **operations integrators**".

Appendix 6.

The Value Chain

The value chain is a tool introduced by Porter (10) in 1985 in order to diagnose and enhance competitive advantage. In Porter's words "Value Chain analysis helps a manager to separate the underlying activities a firm performs in designing, producing, marketing and distributing it's product or service".

Porter's ideas on the value chain may be summarized as follows:-

> "To diagnose competitive advantage, it is necessary to define a firm's value chain for competing in a particular industry. Starting with the generic chain, individual value activities are identified in the particular firm......
>
> Defining relevant value activities requires that activities with discrete technologies and economics be isolated. Broad functions such s manufacturing or marketing must be subdivided into activities. The product flow, order flow or paper flow can be useful in doing so. Subdividing activities can proceed to the level of increasingly narrow activities that are to some degree discrete. Every machine in a factory, for example, could be treated as a separate activity. Thus the number of potential activities is often quite large.......
>
> Although value activities are the building blocks of competitive advantage, the value chain is not a collection of independent activities but a system of interdependent activities. Value activities are related by linkages within the value chain. Linkages are relationships between the way one value activity is performed and the cost or performance of another.......
>
> Linkages can lead to competitive advantage in two ways: optimization and coordination. Linkages often reflect tradeoffs among activities to achieve the same overall result. For example, a more costly product design, more stringent materials specifications, or greater in-process inspection may reduce service costs.......
>
> Exploiting linkages usually requires information or information flows that allow optimization or coordination to take place. Thus, information systems are often vital to gaining competitive advantages from linkages. Recent developments in information systems technology are creating new linkages and increasing the ability to achieve old ones.......
>
> Linkages exist not only within a firm's value chain but between a firm's chain and the value chains of suppliers and channels. These linkages, which I term vertical linkages, are similar to the linkages within the value chain - the way supplier or channel activities are performed affects the cost or performance of a firm's activities (and vice versa). Suppliers produce a product or service that a firm

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