

Manufacturing, Production and Business Processes

The Sector

Production activities - manufacturing, mining and quarrying and the utilities - account for 27.5% of UK GDP and the manufacturing segment of the production sector represents 22.6% of GDP. There are 130,000 manufacturing companies with a total of 4.4 million full-time employees. Almost 30% of manufactured output is exported and this accounts for 60% of UK exports. Over 1 million jobs in the service sector are directly dependent upon the manufacturing base and a further 3 million are indirectly dependent. Despite significant improvements in recent years, the UK manufacturing base in aggregate has lower productivity and lower growth than that in other industrialised nations.

The Future

The panel envisage a successful future where industrial competitiveness and wealth creation have been improved through increased productivity and increased exports resulting from more effective business processes, improved skills and organisational effectiveness, innovation, and improved product and process technology.



Recommendations

The panel has recommended action in the following areas:

- **Increased Emphasis on Business Processes:** Research on best practices, together with diffusion of practices throughout industry.
- **Technology Priorities for Competitive Manufacturing and Production:** Generic needs include multi- discipline projects; improved process plant technology; new sensors and controls; modelling, simulation and visualisation; material processes; IT and communications; and better academe/industry alignment.
- **Improvements Through Education and Training:** Particularly for business process/ teamwork skills and continuing education.
- **Extended Vision for Manufacturing and Production Businesses:** Better market knowledge, "foresight", and innovation.
- **Improved Communications and Support Networks:** Customer, partner and supplier networks; and network services for manufacturers.

- National Infrastructure for Improved Competitiveness: Action in particular for education, transportation, deregulation and finance.



Forward with Foresight

The panel recommends action in three priority areas:

Business Processes

Priorities:

- Improve knowledge and awareness of best business process practices
- Diffuse best practices throughout manufacturing and production industry
- Develop integrated design processes with product life-cycle support
- Improve training, organisation and management for business process effectiveness
- Perform international competitive benchmarking - including the science base
- Improve innovation, market knowledge, vision and networks of alliances

Actions:

1. Research Councils must create a national programme of research into best practices
2. The DTI and Trade Associations must assist industry implement best practices
3. The Education Departments and others must improve education and training on business processes.

Technology

Priorities:

- In the science base, increase multi-disciplinary projects with manufacturing objectives
- Improve process plant productivity, quality, repeatability and effectiveness
- Develop processes, plant and equipment which meet future environmental needs
- Develop advanced sensors and controls

- Improve processes to effectively use new materials
- Develop modelling, simulation and visualisation for technical and business use
- Develop integrated IT systems supporting effective business processes
- Give recognition to academics contributing to industrial success

Actions:

1. Research Councils must increase emphasis on selected generic technologies
2. The HEFCs must change their research assessment criteria to assist industrial collaboration
3. Industry must improve its technology management, and share knowledge with academe.

National Infrastructure

Priorities:

- Through education, improve understanding of manufacturing and production
- Through education, increase teamwork, communication and related skills
- Improve collaboration between industry and the science and technology base
- Strengthen networks which diffuse best practice and communication between firms
- Provide competitive base for a thriving manufacturing and production industry
- Encourage finance to assist longer term investment in industry

Actions:

1. Government must provide a competitive infrastructure and assist industrial growth
2. Government must work with industry and encourage firms to invest in the longer term.



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Progress Through Partnership: Preface

The Technology Foresight Programme is a major initiative which was announced in the 1993 White Paper 'Realising Our Potential'. The Programme brings together industry, academia and Government to consider how the UK can best take advantage of opportunities to promote wealth creation and enhance our quality of life. The Programme has been driven forward with great energy and enthusiasm by the 15 independent Technology Foresight panels. The Programme has reached out to over 10,000 people.



I believe that the current findings from the Technology Foresight Programme will prove invaluable. They will help businesses, academic institutions and policy makers to **Progress Through Partnership**. I know that, encouraged by the Office of Science and Technology, several other organisations are embarking on the Foresight approach. Only by bringing together science and business more effectively will we secure the economic performance necessary to maintain our competitiveness.

The Foresight panels have generated visions of the future which will lead to more informed decision-making in both the public and private sectors. I would like to thank them for their wholehearted devotion to this important mission. We now look forward to a busy and exciting period as the results of Foresight are drawn together and the Foresight process moves forward.

The Rt Hon David Hunt MBE, MP Cabinet Minister for Science and Chancellor of the Duchy of Lancaster

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FOREWORD

The competitive strength of manufacturing and production industry has a crucial influence on the future success of the UK economy. Technology Foresight panel members from industry, academia and government have studied the key drivers of change and future industrial scenarios. The studies have enabled the Panel to recommend a number of actions that will improve the competitive strength of industry and the effectiveness of supporting infrastructures such as science and technology base.

Product and technology development must be excellent but this alone will not guarantee success. The Foresight study has highlighted the need for improved business processes at every stage from product definition through to product delivery. The study has also highlighted the need for well educated and trained teams of innovative people with the competence and drive to fulfil their vision of a successful future.

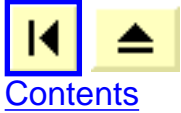
I would like to thank Panel members who have contributed much expertise and time to the Technology Foresight Programme. Furthermore, the Panel has been assisted by many individuals and organisations whose knowledge and opinions have been most valuable. I am pleased to note that the Foresight Process has demonstrated that teams with a wide range of skills and viewpoints can rapidly work together and develop far-reaching views of issues and opportunities in this particularly large and diverse sector.

The Panel will assist the implementation phase of the current Programme, and recommend regular iterations of the Foresight Programme in future years.

Dr. D. Grant



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1. EXECUTIVE SUMMARY

Manufactures account for 60% of UK exports and consequently success in the manufacturing sector of the economy is vital to future national prosperity. A strong manufacturing and production base generates wealth by efficiently creating and selling competitive products in the growing international marketplace. Competitive strength results from technological proficiency and effective business processes. Despite good performance in a few manufacturing sectors, UK-based manufacturing as a whole has not performed as well as that in other industrialised nations in recent years. Productivity has improved, but is still below achievements elsewhere. Export volume has increased, but has not regained its earlier share of world markets. Action must be taken to strengthen the manufacturing base.

The Foresight Sector Panel of 25 members from industry, academia and government has consulted widely with organisations and individuals. It has studied trends, future scenarios and drivers of change for UK-based manufacturing and production industry over the next 20 years. The objective of the study was to examine technological and other factors that can be changed to improve competitiveness, wealth creation and the quality of life. The studies have identified market opportunities as well as internal improvements for manufacturers and their supporting infrastructure.

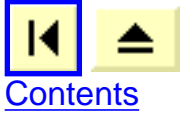
Some of the more important influences on manufacturers include rapidly increasing internationalisation and the growth of new markets and competitors, enhanced by improving world-wide educational standards; increasing competition for market share and the need for innovation; and the growth of consumerism, environmental concern and regulation.

Future success for UK-based manufacturers requires greater productivity, increased exports and more sales in the domestic market, innovation, improved product and process technologies, more effective business processes - with wide and fast dissemination of best practice throughout industry, better teamwork skills and organisational effectiveness, and rapid integrated design and production processes. Priorities for improvement are in business processes, technology and infrastructure.

Key recommendations include new initiatives to improve business processes. Further improvements will be achieved through commitment to education and training; increased market vision, creativity and innovation; and better communications networks. Technology emphasis includes multi-disciplinary activities, process plant and manufacturing methods, sensors and controls, modelling and simulation, materials and material processes that are environmentally compatible, and information technology. The national science and technology base must work in closer co-operation with industry and must maintain excellence in basic research. The government must ensure that the UK is a competitive base for a thriving manufacturing and production industry. Policies and measures must encourage and help firms to invest in the longer term.



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2 INTRODUCTION

2.1 SCOPE

The Office of Science & Technology (OST) proposed that the **Manufacturing, Production and Business Processes Panel** should review : 'Demand for goods and processes; in particular, systems for the management and control of design, manufacturing and production processes, inventory control, accounting, distribution etc. The design, construction and use of machinery for the manufacture or production of goods. Human factors and organisational design. Business processes and infrastructure'. The panel has studied trends, key issues and future scenarios for manufacturing and production activities based in the UK It has taken a broad view of manufacturing and production, recognising that other panels have analysed particular sectors in detail. Objectives for the reviews and recommendations of this panel are to enhance **competitiveness, wealth creation, and quality of life**. The studies have identified market opportunities as well as internal improvements for manufacturers. Large markets exist for UK-based suppliers of process plant and equipment and the many other products and services that help manufacturers meet new and challenging goals.

2.2 OVERVIEW OF CURRENT UK MANUFACTURING AND PRODUCTION

Production activities (as defined to include manufacturing industries, mining and quarrying, and electricity, gas and water utilities) accounted for 27.5% of UKGDP in 1993. The manufacturing segment of the production sector represented 22.6% of GDP, and was generated by 130,000 companies with a total of 4.4million full-time employees. Almost 30% of UK manufactured output was exported and this accounted for over 60% of UK exports. In comparison, the large service sector of the economy had an export content of less than 15% and accounted for less than 25% of UK exports. Over 1 million jobs in the service sector are directly dependent upon the manufacturing base, and a further 3million are indirectly dependent. Manufactures account for 50% of consumer purchases and 60% of investment. [1,2,3,4,5,]

UK manufacturing consisted in 1992 of five major sectors: Food and Drink, Electrical Engineering, Paper Printing and Publishing, Chemicals, and Mechanical Engineering.

The relative size of the larger manufacturing sectors was [1]:

Sector	Percentage
Food and Drink	14.1
Electrical Engineering	13.5
Paper, Printing and	11.6
Chemicals	11.4
Mechanical Engineering	10.9

Textiles and Clothing	5.8
Motor Vehicles	5.6
Metal Products	5.5
Minerals	4.8
Aerospace	4.7
Metals	3.1
Other	9.0

2.3 THE NATIONAL SIGNIFICANCE OF MANUFACTURING

Many recent studies and reports note that manufacturing industry, and in particular its ability to export, is crucial to the future health of the UK economy. It is reported that the service sector of the economy, although very important, can only be expected to export a maximum of about 20% of its output and is today achieving 15%. Manufacturing, in contrast, has increased its export content from 25% to 30% in the last decade. [1,4,5]

The future prosperity of UK-based manufacturing industry depends upon the combined efforts of many stakeholders in the private and public domain. This Foresight study has recognised the need to address a combination of important technical and business issues, and also the organisational, skill and social factors associated with the people who must work together to achieve success.

2.4 THE PANEL AND ITS PROGRAMME OF WORK

The panel selected by the OST during its pre-Foresight consultations and nomination process, comprised individuals with a wide range of relevant experience. Members were drawn from manufacturing industry - large and small, with UK and overseas ownership, from academe - covering a wide range of disciplines, from government departments and trade associations.

Panel Members:

Dr D Grant	GEC plc	Chairman
Prof G N Gilbert	Univ. of Surrey	Vice-chairman
Dr F J Winter	OST (& ICI)	Technical Secretary
Prof R Coombs	UMIST	Facilitator
Prof D Bell	University of Ulster	
Prof K Bhattacharyya	University of Warwick	
Mr A Boswell	ICL	
Prof A S Carrie	University of Strathclyde	
Mr A N Dicken	ICI	
Mr R Geary	Picon	
Mr I M Harris	Bonas Machine Company Ltd	
Prof B Hon	University of Liverpool	
Prof T M Husband	University of Salford	
Prof K Khodabandehloo	University of Bristol	

Dr S Manton	University of Warwick
Dr A Mawson	Electra Innvotec Ltd
Dr G F Moore	BICC Cables Ltd
Prof C New	Cranfield University
Dr J Parnaby	Lucas plc
Prof J Perkins	Imperial College
Prof J A Powell	University of Salford
Mr P Robson	NIS Ltd
Mr R M Rumbelow	Dept. of Trade & Industry
Mr D Saynor	Spring Research Manuf. Assoc.
Prof D Stout	London Business School
Mr M Taylor	Bridgeport Machines Ltd
Mr L M Teasdale	Brit. Pump Manuf. Assoc.

The panel began work in April 1994, and held meetings at approximately two week intervals through to February 1995.

The panel has consulted widely to determine the more important trends and issues influencing future success for UK-based manufacturing industry. A preliminary view of the key drivers of change and potential future scenarios was developed in May and June 1994. A list of 82 Topic Statements was developed during July for a Delphi questionnaire sent in August to over 900 individuals considered to be knowledgeable about the topics. These topic statements emerged from many issues identified by the panel during its discussions and through its consultations.

Five regional meetings during October and November 1994 gave panel members an opportunity to consult with groups of individuals who had responded to the Delphi questionnaire and were willing to discuss issues in detail. Meetings were chaired by panel members and were held in Strathclyde, Teesside, Warwick, Bristol and London. At most of these meetings the host invited two or three speakers - mainly from local firms - to give presentations on topics considered relevant to the work of the panel. In total, 129 individuals attended the meetings and 11 presentations were given.

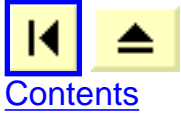
Communication with each of the 14 other panels has been achieved by nominating appropriate panel members to liaise with each one. Members considered that all panels had important contributions to make to the work of the Manufacturing, Production and Business Processes Panel - and subsequent analysis indicated that this was so. For example, 312 Delphi statements from other panel's questionnaires related to manufacturing matters.

The panel has obtained views from a wide range of sources. Written submissions have been received from many individuals and organisations, and have been taken into account during panel meetings and the wider consultation process. Many recent studies and reports are directly relevant to this programme, and are listed in the References section. Work involving panel members, which led to publications during the course of this study included The House of Commons Trade and Industry Committee second report on Competitiveness of UK Manufacturing Industry [1] April 1994 - and is particularly noteworthy with recent evidence from 97 sources. Similarly the Government Paper on Competitiveness [6] Cm 2563, May 1994 - provided much relevant information. In addition to the panel's own programme of meetings, discussion groups on specific topic areas were arranged by The



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Manufacturing, Production and Business Processes



3 FOUNDATIONS

3.1 PRODUCTION AND MANUFACTURING IN THE UK

3.1.1 The Manufacturing Segment of The UK Economy

As noted in Section 2.2, manufacturing accounts for 22.6% of GDP. There are 130,000 manufacturing companies in the UK with a total of 4.4 million full-time employees. Over 60% of UK exports are manufactures, consequently the economic success of the nation is very dependent upon the achievement of its production and manufacturing industries. [1,2,4]

3.1.2 The Size Distribution of UK Manufacturing Companies

Of 130,000 manufacturing companies in the UK, 1100 have more than 500 employees, 3600 have between 100 and 500, and the large majority employ less than 100. The UK is particularly strong in large multi-national companies, with 43 of the world's largest 500 compared to 33 in Germany and 32 in France. The UK has half the percentage of medium sized firms (100 to 500 employees) compared with most European countries. Many observers describe this as a serious gap. The UK also has fewer companies in the 20 to 100 employee range. [1,4]

3.1.3 UK Manufacturing Output

In aggregate, the UK manufacturing base has performed less well than many competitors in the growing international market. UK domestic production has been rising more slowly than expenditure on manufactures; and the trade balance, which became negative in the early 1980s, has not seen adequate recovery. UK total manufactured output has marginally increased since 1960 whilst that in Germany has doubled, in France has tripled and in Italy has quadrupled. Japan's output has increased tenfold. (Fig. 1) [1]

UK manufacturing output in total grew during the 1980s by about 1% per annum. The UK manufactured share of the growing domestic market declined by around 1% per annum but exports grew by 4% per annum over this period. The UK share of world manufacturing exports declined rapidly in the 1970s but has maintained a 6% share since the early 1980s. (6% of the world export market is equivalent to 8% of that held by the eleven major exporters.) Japan, in contrast, has more than doubled its share to 16%. Germany has maintained its share at 20% over three decades. (Fig. 2). [1,4,6]

3.1.4 UK Manufacturing Productivity and Employment

UK-based labour productivity is, in aggregate, below that in many other industrialised nations, even though it increased by 46% during the 1980s. (Fig. 3). This 46% productivity growth was accomplished through efficiency improvements, headcount reduction (Fig. 4), and by market focused measures to

promote business growth and improve competitiveness. However, despite particularly high growth in the last decade through new and improved practices, manufacturing productivity remains below that in most industrial nations. Some manufacturing sectors perform better than others. Although, for example, the automotive component industry has been under customer and competitive pressure for some while, nevertheless a survey just completed in 1994 of 71 automotive component suppliers world-wide found UK productivity to be 56% of that in Japan, 66% of USA, 63% of France and 95% of Germany. The survey notes that although UK labour costs are currently below those in many nations, productivity is lower and quality was also poor. [4,6,7] (Analysis of employment statistics requires care because part-time employees and service industries perform some tasks previously undertaken by full-time employees.)

The number of full-time employees in manufacturing has halved since 1970. The reduction of 30% in the 1980s compares with reductions of 17% in France, 11% in Italy, 5% in the USA, no change in Germany and an increase of 13% in Japan. [1]

(Analysis for employment statistics requires care because part-time employees and service industries perform some tasks previously undertaken by full-time employees.)

3.1.5 UK Domestic Supply Chains

Local supply networks in the UK have declined in the 1980s. Some manufacturing sectors are now more dependent upon overseas sources of components or materials, whilst some are more reliant upon foreign sources of process equipment. Suppliers who formerly satisfied small local markets have been replaced by those addressing global markets and achieving economies of scale by manufacturing in the lowest cost location. Increased international transportation and communications, and reducing trade barriers, have assisted these changes. Between 1979 and 1989 import penetration as a percentage of domestic demand for manufactures increased by 10 percentage points, from 27% to 37%. During this period, exports as a percentage of UK production increased by only 5 percentage points, from 25% to 30%. [4,5]

3.1.6 Investment in Manufacturing

A much studied factor behind the slow growth of UK-based manufacturing has been the low level of capacity-creating investment. Some observers consider that this is a consequence of low profitability in manufacturing, particularly in comparison with the service industry. (Fig. 5). Manufacturing profitability improvements during the 1980s are said to have been eroded by increased pay, increased competitive price pressure and increased dividends. (Fig. 6). Real profits in manufacturing increased by 44% between 1979 and 1989, but real investment increased by only 12.8%. [4,6]

Manufacturers' expenditure on plant and machinery in 1992 was #10.4 billion, and expenditure on new buildings and works was #1.4 billion. The trend in capital expenditure shows growth during the 1980s followed by a steep reduction in the early 1990s (fig. 7) [2,3]

3.1.7 Industrial Expenditure on Research and Development

UK Industrial R & D expenditure was £9.1 billion in 1993 and over 90% of this expenditure was carried out in just 100 companies. It follows that the great majority of manufacturing companies spend very little on R & D. Across all of manufacturing industry, R & D represents 2.4% of sales - although some sectors exceed 15% and some spend less than 1%. R & D expenditure by industry has grown

from £6.0 billion in 1986 to £9.1 billion in 1993, or 4% in real terms. Business enterprise R & D spend as a percent of GDP was less than most competitors achieved (Fig. 8). [1,8,12,22]

3.1.8 Foreign-owned and Transnational Companies

In 1990, foreign-owned firms accounted for 25% of gross output, 16% of employment and 27% of capital expenditure in UK manufacturing. Transnational companies, both UK and foreign-owned, were responsible for 80% of UK exports. [4]

3.2 SCENARIOS AND DRIVERS OF CHANGE

3.2.1 Scenarios Developed by the Panel

The panel outlined and debated two sets of contrasting scenarios from a 2015 viewpoint in order to identify the most important drivers of change and their likely consequences. In all cases the studies examined the conditions that would be necessary to achieve a successful position. The elements of success comprised wealth creation, competitiveness and quality of life. The studies were neither rigorous nor fully quantified, but were useful in identifying the factors most likely to influence the future of UK manufacturing.

The first scenario looked at the successes possible from a UK base dominated by Design/Marketing/Business Management ('Design-Shop') activities, and contrasted them with a UK dominated by Production/Manufacturing/Assembly ('Manufacturing-Shop') activities. The second pair of studies contrasted the relative successes of small and medium sized enterprises (SMEs) of various types, with large multi-national enterprises (MNEs) having both UK and overseas ownership.

Each of the contrasting scenarios was independently developed by half the panel who then defended it against questions from the opposing group. The scenarios were subsequently refined where necessary. Brief outlines of the scenarios are presented below:

A) UK 'Design Shop' in contrast with UK 'Manufacturing Shop'

The Design Shop scenario describes the UK in 2015 as a country with excellent knowledge of global markets, their specific trends and future requirements. A highly educated and extremely innovative workforce would identify product opportunities throughout the world, specify and design the products on behalf of low cost manufacturers elsewhere, and work with the selling, service, financial and other support groups necessary to make the product a success in the target markets. These leading-edge 'design shop' companies would be supported by a world-class science and technology base; and related skills and activities such as rapid prototype developers, IT system developers, simulation and design tool developers. Communication networks would span the globe, and working patterns and working times would fall into line with the requirements of each opportunity as it arises. A strong financial services sector would support this global network. Entrepreneurs would flourish throughout this rapidly growing economy.

The Manufacturing Shop scenario describes the UK in 2015 as a country with many high technology, high skill, high quality manufacturers with their supporting infrastructure of machine tool and automation systems companies. This scenario considered that the country could not compete with low wage economies for the low technology end of the product spectrum, but had chosen instead to become Europe's leader in high technology manufacturing - giving high added value. A responsive,

motivated and well-trained workforce operate, and automate where necessary, the most efficient and environmentally clean manufacturing operations in their chosen sectors. A strong supporting national infrastructure would include excellent transportation systems and fast routes to the rest of Europe. A thriving services sector would support the manufacturing companies. Closely coupled local supplier networks provide specialist materials and equipment. Government planning for education, taxation and infrastructure was a key to success in this scenario.

B) MNE success in contrast with SME success.

The scenarios looked at success from a company viewpoint. They also considered that the UK would continue to have a mix (undefined) of large and small companies.

The first scenario describes a world in 2015 with many types of successful multinational enterprise, including current forms. Some MNEs would comprise groups of loosely related companies - perhaps fairly autonomous - in each location. Others would comprise international networks supporting a limited product range. In many sectors the high cost of product development or the high cost of production plant would have encouraged mergers or alliances on a massive scale. The successful company scenario in 2015 shows MNE advantages from economies of scale, from the flexibility of operations between and into growing markets, and from the economies gained by choosing and changing location for factories and technology development. Other benefits from their scale of operation would include global brand image, purchasing power, breadth of partnership links, financial strength, availability of known and trained people, ability to protect and defend IPR, and wide knowledge of international trade and growing markets. Global MNEs might by 2015 have much less loyalty to a specific country. They would, however, take care of environmental matters and show social responsibility to maintain a good international image under scrutiny from a global media network. In 2015 more MNEs - perhaps many in capital goods - would have climbed the value chain to provide services based upon their products or their international skill base.

The second scenario shows that small and medium sized companies would continue to exist in large numbers and with a wide range of characteristics. For many, success would come from their entrepreneurial spirit. Their flexibility and speed of response to a fresh opportunity would allow them to win new business quickly. Some must be located close to their customers and consequently their own success would be determined by the whole supply chain remaining viable in the UK. Many would focus on a very narrow market or technology niche, but would gain international business through their deep knowledge, networks and growing reputation. The world-wide availability of finance and technology in 2015 would give greater choice of location to new businesses. Those who create companies in the UK would have done so for personal location reasons, for market access, people, finance or for links with the science and technology base. Good communication systems would allow networks of SMEs to join together and with larger MNEs, for both long and short term business relationships. Communications and networking would be key determinants of success.

The scenarios in (A) represent possible, but extreme, modes of success for UK manufacturing. The real outcome, and the relative role played by SMEs and MNEs, will depend upon how the UK responds to a range of drivers of change. The most important are listed in Table 1.

3.2.2 Drivers of Change

The Panel's study of the drivers of change for manufacturing and production drew upon information from Panel members, a questionnaire sent to individuals identified during the OST's pre-Foresight

exercise, discussions at regional meetings, views from trade and other organisations, and a review of much relevant literature. As well as developing its own scenarios, the Panel reviewed published scenarios. This included work by the Policy Studies Institute [5]. Note reference [9] also. Table 1 indicates many of the influential factors considered by the Panel when assessing the key drivers of change for UK-based manufacturing industry. Some factors appear, or could appear, in more than one STEEP (Social, Technological, Economic, Environmental and Political) category. In many scenarios, a number of factors act together to influence - or be influenced by - manufacturing and production businesses. The table highlights factors considered by the Panel to be worth specific comment. Note references [1,5,9,11,13,14,15] also.

- Lifestyle changes, family, quality of life, health, **consumerism, demand for more - or better - or choice**, leisure demands
- Employment flexibility, insecurity, mobility, full/part time, age profiles, new competencies, automation, more-with-less, resentment from unemployed, Social Chapter
- Mobility of workforce, global professional, migrant workers, teleworking
- **Globalisation of markets**, mass markets versus customisation, cultural distinctions
- **Inequality of wealth and income** - in country & between nations, class jealousy, growing underclass, resentment
- Crime/security - personal and business
- Global media - influence on people, media-based criticism, instant comment, n
- Demographics - ageing, global population growth, urbanisation, rising education, **global levelling of education**

Technological

- Electronics - computation, **Information Technology, telecommunications, visualisation & display, sensing & control**, computer integrated manufacture, data-bases, standards, **open systems**
- **Materials and material processing, coatings, micro & nano technologies, biomaterial recovery - reuse - or disposal, waste elimination, rapid processes/low energy processes**
- Automation, systems engineering, **non-invasive sensing**, mechanical actuation, conveying & transport, optical technologies, image processing, physical - chemical - bio metrology
- Ergonomics, human factors, safety & hazard analysis, voice recognition, computer aided design & manufacture, **modelling & simulation**, light weight structures, building construction
- Basic sciences, mathematics, scheduling & planning, risk analysis, non-linear systems, management, business process management
- Bioscience, ocean technologies, space technologies, **multidisciplinary research**, mobility of/ access to technology

Economic

- Trading power distribution - **protectionism, blocs, bilateral deals**, multinational company strengthening compared with state
- **Internationalisation of business - distributed manufacturing operations, global competitors, global modular businesses, distributed supply chains, use of cheapest sites**
- **Emerging economies - new markets, technology transfer agreements, new competitors**
- Core business focus - move to upstream value adding, specialise, service industry
- Finance - wider availability, rapid money movement, global investment
- Shareholding - internationalisation, rate of returns required, power, speed of change

- Global debt distribution - banking risks
- Risk aversion - changing technology, regulation, litigation, cost-of-innovation
- Affluent population bulges - changing age and geographic spread of purchasing power
- Move from public expenditure - more choice, personal spending changes

Environmental

- **Public awareness - greenhouse**, pollution, quality of life, pressure groups, legislation, regional differences
- Increased scientific knowledge - possibility of 'new' concerns, more control
- Pollution - prevention, clean-up, clean technologies
- New pollutions - electromagnetic, noise, light
- **Life-cycle issues - recycling, reuse, disposal**
- Non-renewables - **energy saving**, alternative materials, recycling
- Water - quality, availability, distribution
- Energy - demands, sources, economics
- Disasters - natural, man-made, prevention, clean-up

Political

- Regulation/legislation - environment employment products, trade, taxation, UK compared with EU and other countries
- International relations - trade becoming a key driver
- **Rise of new powers - China S E Asia, Islam**
- Europe - effect on UK, central control, ecu, **regulation**
- National security - changing scene, changing needs
- **Education & training policy - retraining**, industry/academe interrelationship, schools
- More pressure groups - environment, industry, transnational, media influence Privatisation - competition, threat/opportunity
- Alienation from politics- professional politicians, apathy, government by media

Notes: The list identifies many of the factors considered during debates - but is not comprehensive. Items shown in **bold italic** print are considered to be particularly influential in the 20 year timeframe.

Some aspects of the many drivers of change are outlined below:

3.2.3 International Issues

Current trends suggest that internationalisation will continue to strongly influence the future direction and prosperity of many UK based enterprises. Although some manufacturers are constrained by local markets, or have ambitions that are satisfied locally, a great number serve overseas markets from the UK. Some are developing production operations overseas. Conversely, as noted in Section 3.1.8, a large number of manufacturing operations in the UK are owned by overseas companies. [4].

Throughout the world, the basic resources of manufacturing are becoming more widespread and more mobile. Factories, equipment, supplies, people, technology and finance regularly cross borders that once protected local trade. Also, telecommunications and transportation networks continue to grow and encourage the wider distribution of trade and manufacturing. [6,10,16]

Emerging economies, many with highly skilled people, are rapidly developing low cost manufacturing operations to satisfy local needs and to capture both local and export business from more costly suppliers. Furthermore, the worldwide availability and diffusion of technology is enabling countries with good skills and educational standards to develop high technology businesses rapidly. The newly developing and industrialising economies represent a combination of 'opportunity' and 'threat' to established exporters from the UK. As a market, they demand increasingly advanced goods. As a supplier, they can often compete with advanced products at low cost.

There are many possible scenarios for UK-based manufacturers influenced by increasing levels of international trade. The changes within the next 20 years will vary from sector to sector, however it seems likely that the more successful UK-based manufacturers will have excellent international sales networks; strong links with emerging economies - and develop local factories or local partnerships where

scope; knowledge of, and adaptability to, political and trade policy changes; extensive market, regulation, customer and competitor knowledge; responsive local customer support and service; and an international logistics and supply chain network. While it seems unlikely that widespread protectionism will inhibit this scenario, it is recognised that some countries will develop protective measures.

Another important and related influence is the internationalisation of finance and the effects of foreign shareholding or foreign ownership. It is also likely that the trend for cross border acquisitions, mergers and alliances will continue and it is possible that these truly international enterprises will show less loyalty to single or base nations. [10]

3.2.4 Changing Customer Requirements

Demographic and social changes are rapidly transforming many markets. The growing levels of international consumerism are creating demands for previously unavailable, unaffordable or non-essential goods. Furthermore, ageing populations in some countries focus new demand on healthcare products for example, whereas the affluent young in other nations focus demand towards personalised products. Changing patterns, and growing levels of requirement attract new market entrants and cause existing suppliers to compete in new ways. Many manufactures have improved their products features, quality, value-for-money, delivery, customer service and attention to customer future needs. [5,9,11,17]

These trends are likely to continue, and will probably accelerate in the emerging economies. Successful manufacturers will be those with best understanding of customer needs; best access to customers; best advertising and reputation; rapid response to changing requirements; local and rapid product customisation where appropriate; and related competitive advantages through product features, value, quality, reliability and support. All internal processes will support and enhance this market focus.

Businesses who today see themselves as manufacturers, may - through their greater customer focus - operate in future more as a service provider. Many businesses will disperse their operations. Product engineering will be centred at the location with the best technical resources, basic production will be performed at the lowest cost site whether owned or in partnership, and finishing operations or customisation will be fulfilled by local entities servicing specific customer needs.

3.2.5 Business Processes and People

The growing international markets and emergence of low cost - but competent -new manufacturers will intensify competition and cause established manufacturers to continually improve their business processes and organise people to greater effect. Trends suggest that many UK-based manufacturers often introduce improvements later than their overseas competitors, and are less likely to introduce radical change. [1]

For many years manufacturers world-wide have sought improvements to product features, quality, throughput, productivity, yield, lead-time etc., by automating or improving their operations stage-by-stage. This was generally with a predetermined organisation and functional model of the business. In recent years many businesses have realised that automation, integration, Information Technology (IT), Just-In-Time (JIT) methods, empowerment, Total Quality Management (TQM) and other initiatives, although necessary and beneficial, were insufficient to match or beat their best international competitors. This has caused them to re-examine their whole business, and focus upon value-adding processes rather than upon historically created functions or departments. Recently, manufacturers have begun to use these analyses to change fundamentally their businesses, and have achieved world-leading positions. The resultant change process is currently described as Business Process Re-engineering (BPR). See Annex I for a further discussion on business processes.

Although many manufacturers are presently analysing their business processes, only a small percentage of UK-based companies have yet implemented fundamental business process changes. Those who have succeeded often report dramatic improvements. Sufficient examples of success exist, particularly overseas, to convince other manufacturers that they must embark along this path. Many manufacturers, though, do not have sufficient knowledge of their competitors to determine the magnitude and direction of necessary changes to achieve an acceptable or leading rank. 'Benchmarking' is therefore an important prerequisite of success.

A company's ability to plan and implement change is determined by the skills, organisation and management of its workforce. In recent years many businesses have expanded training to improve skill levels, and have introduced schemes to enhance the involvement and contribution from employees. Initiatives such as Total Quality Management (TQM), empowerment and teamwork have often been very successful. Future success will require even greater skill levels to compete with increases elsewhere. It will also be necessary to retrain regularly to keep up with - or lead - rapid changes in markets, products, processes and associated technologies.

3.2.6 Technology

Each manufacturing and production sector has its own particular set of technologies that will influence future success. There are also a number of important generic technologies that affect most manufacturers, and four examples are discussed below:

i)

Materials and material processing are core technologies for many manufacturing and production businesses. A large number of manufacturers can benefit from better selection of existing materials and processes. Looking ahead, novel materials will lead to new or improved products; and novel material processes will improve manufacturing efficiencies, and reduce waste, pollution and process energy. Future success will be built upon the ability to create materials with predictable characteristics, and then link the material processes into the end-

product manufacturing chain in a cost-effective way. Growing environmental concerns and regulation will emphasise the importance of material technology skills to allow product manufacturers to use appropriate materials and then recover, reuse or safely dispose of their products and factory waste. Early use of a new material or process will give a competitive advantage to many manufacturers.

ii)

Sensing and control are core technologies for many production processes. Increasing process complexity and the demand for ever greater quality and efficiency, places stronger demands on sensing and control. Flexible processes, often responding to rapid customer requirement changes, add to the demands of automation. Processes with dispersed supply networks and complex logistics will cause manufacturers to integrate internal production controls with enterprise-wide business systems and with communication links to customers and suppliers. Future success will require integration between technical process control and business process control. Product and process sensors will be non-invasive, rapid, accurate and will cope with increasingly demanding areas such as chemical and bio-sensing.

iii)

Information Technology and Communications are important elements of many manufacturing and production businesses. Those who gain most have carefully integrated their IT systems with good business processes. Looking ahead, the rapid pace of electronic hardware and software developments will continue to enhance the capability of IT and communications. Manufacturing and production efficiency will be greatly improved by networks which enable multi-site operation, customer /supplier links and rapid access to market information, component or material data, and technological and business information. IT has the power to integrate design and manufacturing processes, both within and between enterprises. IT and communications will support new business concepts such as the 'virtual enterprise', where a number of partners with complementary skills join together for the duration of a project, and on completion form new and possibly different links for the next activity. The full power of IT and communications will come when Open Systems compatibility, connectivity, upgrade paths, international standards and other such criteria are achieved.

iv)

Modelling, Simulation and Visualisation techniques have rapidly advanced due to the increasing power of electronics and computation. Modelling and simulation is extending from narrow applications in areas like product design, into far more comprehensive studies of products and their associated production process. Business models are also growing in capability; promising accurate simulations of complex enterprises - and encompassing many resources and their interactions. Visualisation, through such technologies as 'virtual reality' and holographic displays, will influence many aspects of manufacturing and production. High quality interactive displays will, for example, allow customers to select their preference in personalised goods. Visualisation, in association with modelling and simulation techniques, will allow businesses to explore physical models of their enterprises. All of these techniques are expected to make training more realistic and create a better process for enhancing skills. The techniques should also greatly facilitate business and technical decision-making.

3.2.7 Environment

Concern for the environment has become a major public issue in industrialised countries over recent years. Public pressures are persuading governments to introduce legislation. Its influence extends to most aspects of manufacturing and production. Manufacturers must take responsibility for the life-cycle of their products; and for materials, waste, energy and people directly or indirectly involved with production processes. [5]

Products and the product design process will increasingly be influenced by recycling, reuse and disposal issues. There is little pressure at present to design products for a substantially longer life, although it may well increase in some sectors over the next 20 years.

Currently there are large international differences in concern and legislation for environmental matters. Some manufacturers in countries with strict legislation argue that they are less competitive in export markets than manufacturers in countries with few controls. Manufacturers in regulated countries are closing down processes that are difficult or expensive to clean and some are sourcing materials from plants in countries with less control. Many observers believe that customer and international pressures will eventually force all nations to adopt similar and tight controls.

Environmental issues will offer benefits and opportunities to those who can develop clean processes. There will be a large market for many products and services that improve energy efficiency, reduce pollution and waste and allow the reuse or safe disposal of materials.

3.2.8 Education and Training

The competitiveness of manufacturers is largely dependent upon the skills employed at all levels in the enterprise. These skills are influenced by the national educational system and by subsequent training. In quantitative terms, the national educational system is increasing the proportion of youngsters with higher levels of education and is increasing the amount of vocational training. Manufacturing industry has also increased the level of employee training during the last decade. There is much debate about the qualitative levels, considered by some to be lower than in other developed nations. There is concern about the content or relevance of some courses in education and training, and this has initiated actions to improve the dialogue between educators and employers. [6]

Looking ahead, many trends suggest that there will be less variation in educational standards between developed and currently emerging nations. Emerging economies are rapidly increasing their educational levels, and will quickly become competent users of internationally available technology.

The pace of world-wide technology development and the growing rapidity of its communication will increase the demand for retraining and for continuing education. Manufacturers facing ever stronger international competition will devote much more time and effort to training. This may, for example, involve interactive networks between experts in educational establishments and company based trainees.

3.2.9 Regulation

Many UK-based manufacturers are concerned by the increasing burden and cost of complying with regulations - however well-intentioned the regulations may be. Manufacturers, particularly those in small companies, cite problems with the growing complexity and the increasing scope of regulations. The Government's Deregulation Initiative is addressing these concerns at present, though many trends studied in this Foresight exercise suggest that the pressure to increase legislation - particularly in Europe - will affect future scenarios. [18]

The influence of regulations associated with the environment have been discussed; however, an increasing number of other product and process technical requirements will be controlled by formal regulation. The cost of compliance, and the cost and time necessary to prove compliance are issues with a growing impact on competitiveness. In addition to technical regulations there are a large number

of regulations which impact on efficient business processes. With the exception of the Deregulation Initiative, there is little evidence of pressure to reduce or simplify its burden. Regulation therefore appears to be an increasingly influential factor in the next 20 years.

3.2.10 Key Technical and Business Topics

The Panel's study of the drivers of change, scenarios and their influence on UK-based manufacturing, have led to the development of a list of important topics - covering business and technical requirements or issues. This list includes many topics where competitive advantage could potentially be achieved. Each topic was reviewed further by a number of Delphi questions and by discussion at the regional workshops. The topics are shown in Table 2. They are not prioritised, and have been divided into four groups. The lists on the left show the topics that are principally technical issues. The lists on the right show those that are principally business issues. The upper lists address the manufacturing process viewpoint, whereas the lower lists are drawn from a product or market viewpoint. The lists address generic processes and products. In practice, many of these topics are strongly linked and competitive success requires attention to several issues in concert. Individual manufacturing sectors and individual companies will have differing priorities for topics on the list.

Table 2 - Technical and Business Topics

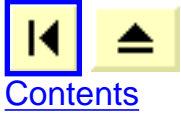
Production Process - Technical	Production Process - Business
Rapid Process	Supply-chain integration
Automation & Integration	Business alliances
Efficient manufacturing plant	Material planning & control
Flexible processes	Skill acquisition
Advanced product & process sensors	In-process efficiency management
Intelligent autonomous controls	Employee skill/efficiency improvement
Reliable, repeatable & Maintainable plant	Organisation, teamwork & Management
Material/component tagging	Decision support
Remote process control	Finance & financial control
Integrated engineering systems	Effective IT
Modelling, simulation & Visualisation	Technology development & Management
New material processes	Project management
New joining/assembly methods	External service providers
Rapid product test methods	Geographically distributed operations
Waste and energy reduction	Benchmarking
Pollution reduction	Quality & Continuous improvement
Integrated IT	Security
Logistics, transport & distribution	Health & safety
Product disposal/recycle	Regulation
Plant for emerging technologies	Standards
e.g. Microtechnologies & Biotechnologies	'Large firm'/'small firm' interrelationships
Product - Technical	Product - Business
Customisation	Sales, distribution, marketing & advertising

Safety, reliability & maintainability
Recycling & disposal
Ergonomics & aesthetics
Design for manufacture
Standards/Regulation compliance
New materials
Emerging & competitive technologies

Market forecasting & competitive analysis
Product planning & lifecycle analysis
Rapid product definition, design & delivery
Commercial/contract management
Customer service & support
Global business and/or local customisation
Intellectual Property Rights (IPR)



Progress Through Partnership: 9 Manufacturing, Production and Business Processes



4 TOPICS

4.1 PRIORITY REQUIREMENTS AND OPPORTUNITIES

Many market, technology, product or process requirements and opportunities have been identified during the Foresight Programme. The term 'requirement' is used here to define an item or need that must be satisfied to improve manufacturing company performance. The term 'opportunity' recognises that the item or process that satisfies the requirement is a possible product or service (often with world-wide application) from UK-based businesses. The priorities listed below are primarily generic topics with broad applicability and influence on a diverse range of production and manufacturing industries. The key objectives for selecting priorities are their effect on wealth creation, competitiveness and quality of life.

Competitive success in manufacturing usually comes from the combination of many factors. These enablers of success have been placed in three categories:

- business processes
- technology
- national infrastructure

The full list of priority topics in each of these three categories is reproduced in Annex 5 Tables 5.1 to 5.4.

4.1.1 Business Processes

Sales and Marketing Processes One of the most important and fundamental requirements for success is the relationship between the manufacturer and the market, and more particularly, the product and the customer. Successful manufacturers have excellent knowledge of their customers including detailed understanding of trends, influences, future requirements, and competitive offerings. With this knowledge, the manufacturer can plan, develop, promote and sell appropriate and competitive products. The fast pace of change in many markets, often with world-wide growth opportunities but with intensifying competition, requires manufacturers to establish networks, communicate effectively and act rapidly.

Novel promotion and selling methods are developing through the increasing spread and capability of telecommunication networks. Many customers (consumer and professional) will wish, for example, to interact with automated product selection databases or intelligent design systems to create a personalised product. Suppliers will also benefit by gaining more information on customer preferences. Product opportunities and technology needs will involve visualisation and interactive systems, communications, and a wide range of network-based services.

Priorities:

- Methods to assist customer/supplier interaction
- Methods to capture information on customer requirements

Product Introduction Processes

Successful manufacturing businesses combine competitive product definition with rapid development processes. Necessary company and personal skills for those involved in product introduction are creativity, innovation, teamwork swiftness and accuracy. The design process must consider the entire product lifecycle, including resources necessary for its manufacture and methods for recycling or disposal. Concurrent engineering processes reduce timescales and enable key considerations such as design-for-manufacture. Formal processes must capture information on customer needs and help generate accurate and competitive product specifications.

New opportunities and technology needs will involve computer-based modelling, simulation, design and prototyping systems. Product data management is a growing priority, especially with the trend towards personalised products. The increasing need to ensure compliance with regulations for product safety, environmental impact etc., will demand greater personal skills, design traceability and greater reliability from design tools.

Improved management skills will be necessary to coordinate cross-functional teams within the organisation and the supply chain. The growing complexity of many products and their markets will cause many manufacturers to form a number of alliances to gain technology or market access. Competent management must be supported by effective IT and communication systems.

Priorities:

- Customer requirement analysis and product specification capture
- Integrated design processes with product life-cycle support
- Techniques for rapid and reliable modelling and simulation
- Product data management
- Design and project management skills

Manufacturing Operations

For many manufacturers the competitive means include productivity, quality, value, service, response time, and responsiveness to change - of products and processes. Automation and integration of processes must extend throughout the supply chain. Many manufacturers will in future concentrate on a smaller set of core activities in-house, and rely on partners to perform associated tasks. Trends include the simplification of processes, deletion of non-essential processes, and making processes tolerant to change. Thus for example, a manufacturer must develop processes which maintain efficiency over a wide range of throughput. Successful manufacturers will have total control over repeatable and reliable processes. Information on key business parameters such as quality, schedule, material flow and inventory, productivity, and financial measures will be current, accurate and will support effective decision making. People skills, organisation and management will continue to be key success factors.

Training and multi-skill acquisition will help manufacturers achieve the necessary ability and

agility to respond to change. Communication throughout the supply chain network will optimise material and work flows. Information technology and communication systems will support and enhance business processes. Product opportunities and technology needs will include IT systems such as improved resource planning and monitoring systems, systems for business process simulation, systems which integrate production controls with business controls and computer-based training systems in the workplace.

Priorities:

- Intensified training of multi-skilled workforces, teamworking
- Tighter process control allied to extended product variation
- Business process analysis, modelling, simplification and integration
- Effective organisation and effective use of IT

Logistics and Supply Processes

Alliances and networks must be integrated to support the manufacturing business process. Information transfer must be rapid and capable of networking through local and international supply chains. Looking ahead, companies in some sectors may more frequently relocate or distribute their operations to minimise supply routes to customers or to material sources. Transportation and distribution methods, and their associated speed and cost, will continue to be a key driver of competitiveness for many manufacturing and production businesses.

Priorities:

- Methods that improve the responsiveness of supply networks
- Methods to optimise the location of manufacturing operations
- Effective transportation and distribution systems

Organisation, Management and Support Processes

As outlined in Section 3, key influences on manufacturing industry include the continuing internationalisation of business; changing customer needs; new and intense competition; emerging technologies; the pressure for financial success; changing skill needs and availability; national and international regulation; and the increasing pace of change in all aspects of business. There are a wide range of possible responses to these influences to achieve greater competitiveness. Some manufacturers will regenerate their business operations - differentiating themselves through novel products and services. Some manufacturers will concentrate on continuous improvement of their current products and processes. Others will focus on fewer products or a market niche, and will reduce their operations accordingly. (See [17]). Whatever the detailed strategy might be, all organisations must be innovative, responsive, flexible, efficient and seek the best opportunities from markets and partnerships.

Specialist manufacturers will form alliances, often for the duration of a particular project. This concept is not new, but the increasing power of communication networks and IT will allow the alliances to form and operate quickly, internationally, and at small scale - suitable for smaller manufacturers. This 'virtual enterprise' model will grow in importance as legal, commercial and other factors reach international harmonisation and reduce the effort and time necessary to form an alliance. Communications networks and other national infrastructures must support the rapid

formation and operation of these ventures.

Management skills will broaden to deal with increasing internationalisation, to adopt competitive business processes, and to improve the effectiveness of organisations and people.

Priorities:

- Vision and strategy for the business
- Vision and strategy to improve competitiveness
- Methods which promote the creation of alliances
- Methods which improve managerial vision and competence

Further support processes are:

Benchmarking

Competitiveness requires a thorough and regular comparison of the key determinants of success. Plans for improvements should be prioritised and quantified by benchmarking against competitors or relevant processes in other industries. Trade associations, government and academe must continue to seek and publish available data, recognising of course that the best manufacturers may become more protective of key information. International benchmarking of advances in science and technology is particularly important to UK-based exporters who collaborate with the UK science base.

Priorities:

- Methods which identify the key competitiveness criteria
- Methods which share information on best practices

Training and Education

Industry-based training must increase to compete with increasing skill levels elsewhere. In addition to their specialist skills, people must develop communication skills and the ability to work in teams. Creativity, innovation and problem-solving abilities are needed by all. Many people will need to retrain or engage in continuing education to keep abreast of developing technologies or business methods. Leadership and other management training will continue to be important. More training should be directed to the needs of the individual. More training should be performed in the workplace. Trainees will interactively link with experts in universities or specialist organisations. For some, computer-based training will link with accurate business simulations.

Priorities:

- Methods which define future skill requirements and present gaps
- Methods which effectively train people at the time and location of need
- Computer-based training

Technology Management Process

Product and process technology represent key assets in any manufacturing company. Technology management involves the prioritisation of current and future needs, the review of progress in the fields of interest, and the selection, management and application of appropriate competitive technology. Scientific and technological information will be rapidly distributed around the international communications networks, thus technology source selection and protection is an important issue. Many manufacturers will maintain their competitive edge through the rapidity with which they exploit new technology. For others, it will be possible to maintain their edge through patent or other forms of protection.

The cost and pace of world-wide technological development will cause manufacturers to focus on core technologies in-house, and purchase or jointly develop less crucial elements from partners. The larger multi-national companies will continue to develop technology wherever the best skills and facilities are located. This may be less easy for smaller companies, however their success is often dependent upon world-class technology. To retain the large companies, and to support the small, it is vital to maintain a world-class science and technology base - and a flow of excellent people. It is also important to develop skills in technology management. These skills will help companies develop appropriate technology strategies and will help academe and other technology developers to prioritise their work.

Priorities:

- Methods to enable companies to prioritise technology requirements
- Methods to assist international technology review and exploitation

4.1.2 Technology

Process Plant Development

Process plant must satisfy the business needs for high productivity, high quality, high yield, reliability, repeatability, maintainability and rapidity - and with increasing needs for flexibility. Plant design will improve through simulation, modelling and visualisation. Some manufacturers will benefit from modular plant, transportable plant, or plant in remote locations - such as underground, underwater or in space. Modular controls and remote controls will be necessary. The increasing concern and legislation for environmental impact will drive the need for low pollution processes, low energy processes, and extensive measures to maintain the health and safety of those in and around the plant. Wherever possible, local suppliers should be encouraged to develop plant equipment.

Priorities:

- Plant modelling and simulation
- Flexible and effective plant that meets future environmental needs

Sensors and Control

Key requirements for effective plant operation include product and process sensors coupled to increasingly capable control systems. Trends are for noninvasive sensors with high accuracy and reliability. Optical sensors and vision sensors are growing in importance. Improvements are needed in chemical and biological sensors. There are opportunities for sensors that measure

customer perception parameters such as taste, smell and touch. Control systems will continue to grow in capability and incorporate novel algorithms and architectures - including 'fuzzy logic' and neural networks'. Controls will extend over a greater number of variables and incorporate concepts such as 'holonic controls'. Predictive and knowledge-based controls will continue to be important. Plant controls should integrate with business process controls to optimise variables such as resource cost or lead time.

Priorities:

- Non-invasive sensors
- Accurate chemical and biological sensors
- Sensors that replicate human senses
- Advanced control systems

Materials and Material Processes

Many manufacturers are involved in the transformation of materials. Consequently material selection and processing are fundamental activities. Key requirements include the development of improved materials and processes - for new and established materials - that predictably fulfil the application need at low cost; with minimum energy, raw materials and waste; with minimum finishing operations; and with rapidity.

Priorities:

- Improved processes to utilise new materials effectively

Pollution, Waste and Energy Reduction

Public concern and international legislation is driving manufacturers to design products and processes to meet tightening environmental regulation. Materials must be selected for product life-cycle requirements such as re-use and disposal. Production processes will be modified or totally changed to reduce pollution, waste and energy. Opportunities and needs include processes, plant and equipment to achieve the improvements, and process simulations that accurately model, predict and optimise pollution, waste and energy. This is a field where competitive advantage will come to those who have novel materials, processes and equipment which cost-effectively meet the increasing environmental legislation.

Priorities:

- Materials with good re-use or safe disposal properties
- Tools to support product life-cycle analysis
- Processes and equipment that reduces pollution, waste and energy
- Plant simulations to minimise pollution, waste and energy

Modelling, Simulation and Visualisation

These technologies can bring great improvements to manufacturing and production businesses. The growing power of computers, coupled with the growing precision of

simulations, will enable manufacturers to improve the quality of technical and business decisions. Furthermore, computer-based simulations will promote realistic training throughout the enterprise. Needs and opportunities include systems which allow customers to visualise a product and interact with a database of possible product variants. Product design systems must cope with increasing levels of product complexity. They must be totally reliable over prescribed operating ranges and should alert users to risks or potential problems. Simulations are also needed to predict and minimise plant energy use and waste. Business simulations should include elements such as supply chain logistics and should grow in scope to cover all important business processes.

Priorities:

- Visualisation of products
- Reliable design tools
- Total production process simulation
- Business process simulation

Information Technology

IT and associated communication technologies influence most aspects of manufacturing. These systems should support and enhance carefully mapped business processes. Specific needs within the enterprise include real-time information presented to those most able to make effective decisions. Further opportunities and needs are for systems that extend far beyond the local boundaries of a manufacturing operation. Networks must extend to customers, to material suppliers and to service providers. IT networks will facilitate business alliances or individual contributions via teleworking. Information management is a key part of business success. It is envisaged that company knowledge databases will benefit from systems which refine data from both internal and external sources - 'data mining' for example.

Priorities:

- IT systems integrated through the supply chain
- IT systems which create new benefits from existing information

4.1.3 National Infrastructure

Education

The crucial importance of education has been referred to in a number of earlier comments including those relating to in-company training. A preliminary requirement is to attract students' attention to manufacturing as an interesting and rewarding career. Manufacturing industry must firstly promote better understanding through examples of its improving performance and future challenges. Manufacturers must work with educators to develop closer links. Schools must introduce pupils to the concepts of manufacturing as part of the technology curriculum and through business, humanities and science teaching. Teacher training, new teaching material and collaboration with industry will be necessary.

Higher education must continue to improve the industrial relevance of scientific, technical, social, humanities and other curricula. Higher education must also ensure that students gain

experience in teamwork, communication, problemsolving, interpersonal skills, business awareness, and business process awareness. Furthermore, it is suggested that students and entrants into industry should engage in Foresight processes and debates. This would encourage them to review the social, economic and other drivers of change which influence markets and manufacturing competitiveness.

Priorities:

- Improve awareness of manufacturing
- Improve teamworking and other skills necessary for future success
- Incorporate foresight activities into the educational process

Science and Technology Base

It is necessary to continue to strengthen the bond between manufacturing industry and the science base. From the industrialist's viewpoint, science and technology form a foundation for competitive business success; consequently it is appropriate to help those involved in science and technology understand industrial business processes, aims and constraints. Researchers and their funding councils, with greater knowledge of industrial requirements, can then assess and guide the industrial relevance of their work. Greater knowledge of manufacturing industry would allow them to express the value of their work in terms of its potential influence on wealth creation, competitiveness and quality of life.

The science and technology base must be regularly and objectively benchmarked with international work in related disciplines. UK university and other national work must maintain an adequate content of basic research across a very broad field. Furthermore, it is important to encourage multi-discipline projects.

For manufacturing industry and academe to share the common objective of a close and mutually beneficial relationship, it is important to ensure that each has goals and rewards for creating successful ventures. Industrialists will see benefits through competitive advantage, market share growth, productivity and quality improvement, and strengthened business and financial performance. The rewards in academe, and the measures of success, may be very different to current measures. Increasing levels of applied work should not be undermined by existing policies in the research funding agencies. The nature and style of research undertaken within UK universities is heavily determined by the research prioritisation strategies adopted by HEFC and the Research Councils. Future research assessment exercises by HEFC must change to reflect the importance of industrially relevant work.

Priorities:

- Improve alignment between industry and the science and technology base
- Encourage multi-disciplinary projects with manufacturing objectives
- Give recognition and incentives for academics to work with industry

Communications and Networking

There is strong support for all initiatives that encourage the formation of networks between groups of companies, networks between companies and the science base, networks with

education and networks with government. Such networks, whether local, regional, national or international encourage the spread of best practices. They can help deliver rapid assistance and can develop into effective supply partnerships.

Current and successful networks include, for example, local and regional groups of firms and bodies who share information on best practices or issues of general value. Government, trade associations and regional bodies must continue to promote and develop these schemes. Future networks will involve telecommunications and IT systems on a regional, national or international scale. Telecommunications-based assistance to industry currently includes market information, company information, libraries, technical databases and related services. This will expand into interactive systems with easier access, and a variety of services which effectively allows the local company to become an international company, or the small company to gain resources far beyond its current capacity.

Priorities:

- Strengthen networks which diffuse best practice amongst firms
- Provide cost effective IT-based support infrastructure

Regulation

Despite valuable activities such as the current UK 'Deregulation Initiative', there appears to be strong international pressure for increased regulation. The objectives for technical regulation may often be sensible and necessary, particularly where the safety of people is concerned. It is important however to distinguish these most important issues from those for convenience only. Trends indicate a growing pressure (in the EU) for mandatory controls in a very wide range of non-critical areas. Manufacturers, particularly those in small companies, argue that the costs and time taken to comply far exceed the benefits - recognising, of course, that they will be unable to sell products if they fail to conform.

Manufacturers must work with government and international bodies to press for sensible regulation. Government and trade associations must alert and guide manufacturers to the effective adoption of regulation.

Environmental legislation will be a key issue in future years, and current evidence suggests that UK-based manufacturers are not well prepared to respond to legislation - or, where possible, to benefit from it. Government, industry and the science base must work together rapidly on these issues.

Priorities:

- UK and EU to minimise burden of regulation
- Need improved institutional frameworks for firms to influence regulations

Finance

There have been many comments during the Foresight process on the crucial influence of finance. Much of the debate has related to the proposition that the UK shareholding structure

leads to 'short termism' from investors and from UK industry. This report will not reiterate the arguments, studies and debates held over a number of years and recorded in many publications and journals.

The Panel note that although a number of very successful companies invest well in resources and R&D, the UK aggregate statistics indicate much less long term investment than many competitors. Furthermore, UK-based manufacturers face stiffening competition from overseas firms with different profit criteria. (These criteria are influenced by the company and its shareholders as well as the taxation and other policies of its national government.) Consequently the competitive drive against manufacturers with unequal and often less onerous financial circumstances requires higher efficiency or greater competence in product and business management. However, productivity statistics and international competitive ranking in a number of sectors suggest that much UK-based manufacturing industry is less efficient than that in other nations - which may reflect inadequate investment, as well as a range of other factors.

Those UK firms with better international competitiveness tend to be either transnational companies with the ability to distribute and finance their operations globally, or companies with a strong national link - to the science base, for example, coupled with international protection of their product technology. As a result, their competitive strength is less dependent upon the cost of capital and required rates of return on investment.

Although most UK-based manufacturers are currently dependent upon local financial markets there is a growing influence from international markets. This is an important future trend. Today, foreign direct investment in the UK - and overseas from the UK - is a higher percentage of GDP than that in many other industrial nations. One third of this flow involves manufacturing industry. As noted in Section 3.1.8, foreign owned companies in the UK have a large influence on national prosperity through employment, their export performance and by developing local supply networks.

Priorities:

- All parties must encourage the supply and application of long term finance
- All stakeholders in manufacturing must consider the longer term
- National policies must encourage manufacturers to invest in the UK

4.2 PRIORITY SETTING

4.2.1 The Approach and Criteria

Priorities have been determined by three procedures:

- A review of the Topic List (Table 2) by the Panel
- The Delphi Questionnaire sent to 900 individuals
- Analysis of views expressed by 129 attendees at regional meetings

The Panel assessed each of the 56 topics in Table 2 to rate its 'attractiveness' and its 'feasibility'. Attractiveness was based on economic and social needs and on scientific and technological opportunities. Feasibility considered the potential to apply (judging industrial strength) and the supporting scientific and technological strengths. Cost and timescale were also considered.

The Delphi questionnaire comprised 82 Delphi topic statements. These statements were developed by the Panel from a very much longer list of issues. The chosen topics were considered to represent many of the more important areas of interest. The Delphi approach is considered to be appropriate for the technical topics but of less value for business topics.

Discussions at the five regional meetings covered many of the Delphi topics, and were particularly useful for collecting information and opinions on business and business process issues.

4.2.2 Delphi Questionnaire

The topics selected by the panel were divided into 14 sections:-

Materials and Material Processing	9	Topics
Measurement and Sensors	6	Topics
Automated Production Systems	7	Topics
Production Process Support Systems	4	Topics
Integrated Engineering Processes	6	Topics
Production Efficiency	3	Topics
Environment and Waste Reduction	6	Topics
Customer Linkage and Supply Chains	6	Topics
Strategic Management	3	Topics
Operations	12	Topics
Personnel and Training	7	Topics
Security	4	Topics
Information Technology	6	Topics
Standards and Regulations	3	Topics

Table 3 lists those topics considered by an average of 225 respondents to have greatest impact on wealth creation. The full Delphi analysis is presented as an annex to this report.

Table 3 - Delphi Topics Ranked by Impact on Wealth Creation

Delphi TOPIC SUMMARY	Mean Score
69 Teamwork & multi-skills	2.68
27 Concurrent engineering	2.67
68 Methods to promote creativity	2.67
33 24 hour planet	2.65
32 Rapid prototyping	2.64
35 Real-time efficiency measures	2.64
16 Self-compensating processes	2.63
65 Computer-based training in the workplace	2.61

29	Networks of experts	2.59
47	Market information networks	2.59
52	Process simulation based upon accumulated experience	2.59
34	Halving number of process steps	2.58
61	SME alliances/networks	2.58
4	Low-cost material processes	2.56
31	Reliable computer aided design	2.56
48	Strategic use of 'STEEP' information	2.54
66	On-line industry-wide expert assistance	2.53
50	Computer-based enterprise model	2.52
7	Close dimensional tolerance from material process	2.51
3	Miniaturisation in products & processes	2.50
51	Real-time automated reporting	2.50
5	Material surface treatment	2.49
44	SME 'virtual enterprise'	2.49
17	Plant for low volume/high variety	2.47
49	Business simulation techniques to overtake competitors	2.46
15	Plant with automated maintenance	2.45
21	Process plant controllers integrated with business process systems	2.44
45	Integrated supply-chain	2.43
20	Training provision at operator-based equipment	2.39
43	Personalised product design by interacting with database	2.37
54	Automated test	2.37
13	Automated vision and optical sensors	2.36
55	Predictive production control software	2.35
42	Customers with interactive access to product database	2.32
57	Modelling to predict and minimise energy use	2.31
11	Non-invasive sensors	2.29
46	Simulation of logistic and supply chains	2.29
2	'Intelligent' materials adapting to stimuli	2.27
41	Knowledge of failure mechanism determines repair/recycle policy	2.27
59	Reconfigurable cells for high volume manufacture	2.27
6	Negligible-friction coatings	2.26
22	Automated assembly	2.25
53	Low-cost electronic tagging	2.25
75	'Enterprise-level' IT software	2.19
10	Sensors to replicate customer perception quality parameters	2.18
30	Regulation approval at design stage	2.18
1		2.16
58	Modelling to predict and minimise waste	2.16

76	Supervisory IT	2.16
18	Stereolithography	2.14

(Top 50 out of 82 Delphi Topics) - Average of 225 respondents

4.3 BARRIERS TO PROGRESS

Current or potential constraints have been categorised into 'STEEP' factors similar to those in Table 1.

Social

- Inadequate education - particularly content and quality
- Inadequate training
- Lack of interest in manufacturing as a career
- Inflexible workforce - unwilling/unable to work with management
- Poor management - lack of skills or vision
- Media-based criticism of manufacturing

Technological

- Lack of technical standards for networks and communication systems
- Lack of 'open systems' and connectivity in IT systems
- Inadequate local sources of advanced materials
- Inadequate business and business process appreciation by technologists
- Inadequate knowledge of world-wide technology development
- Insufficient multi-discipline projects

Economic

- Inadequate funds to support growth (national or company)
- Protectionism and other trade constraints
- 'Short termism' and risk aversion
- Low cost competitors with high technology competence
- Inadequate knowledge of customers or competitors
- High cost of capital or inadequate sources for business start-up

Environmental

- Cost of plant clean-up or of new clean plant
- Cost and availability of clean or reusable materials
- Cost and availability of disposal sites or methods
- Cost of water and energy
- Cost and availability of rapid transport Controls on 'new pollutions' such as noise or light

Political

- Excessive regulation
- Financial policies less supportive of manufacturers than in other nations
- Potential risks from international trade agreements
- Inadequate support for manufacturing infrastructures, including the science base and education

4.4 KEY PRIORITIES

With the increasing intensity of business competition, but increasing market opportunities, it is both necessary and possible to reverse the declining trends shown in Section 3.1. Furthermore, the priorities discussed in Section 4.1 indicate that most actions to improve the competitiveness of UK manufacturing and production businesses also lead to product or service opportunities with a worldwide market.

In broad terms, company and national objectives are to:

- Increase productivity
- Increase exports and satisfy more of the domestic market
- Innovate
- Improve product and process technology
- Improve the effectiveness of business processes
- Improve teamwork skills and organisational effectiveness
- Integrate and accelerate design and production processes

Key priorities in each of the three categories outlined in Section 4.1 are:

Business Processes

- Improve knowledge and awareness of best business process practices
- Diffuse best practices throughout manufacturing and production industry
- Develop integrated design processes with product life-cycle support
- Improve training, organisation and management for business process effectiveness
- Perform international competitive benchmarking - including science base
- Improve innovation, market knowledge, vision and networks of alliances

Technology

- In the science base, increase multi-disciplinary projects with manufacturing objectives
- Improve process plant productivity, quality, repeatability and effectiveness
- Develop processes, plant and equipment which meets future environmental needs
- Develop advanced sensors and controls
- Improve processes to effectively use new materials
- Develop modelling, simulation and visualisation for technical and business use
- Develop integrated IT systems supporting effective business processes

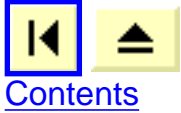
National Infrastructure

- Through education, improve understanding of manufacturing and production
- Through education, increase teamwork, communication and related skills
- Improve collaboration between industry and the science and technology base

- Strengthen networks which diffuse best practice and communication between firms
- Provide competitive base for a thriving manufacturing and production industry
- Have finance available to assist longer term investment in industry
- Give recognition to academics contributing to industrial success



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5 RECOMMENDATIONS FOR IMPLEMENTATION

5.1 KEY RECOMMENDATIONS

The panel has key recommendations in the following six areas

- Increased Emphasis on Business Processes
- Technology Priorities for Competitive Manufacturing and Production
- Improvements Through Education and Training
- Extended Vision for Manufacturing and Production Businesses
- Improved Communications and Support Networks
- National Infrastructure for Improved Competitiveness

5.1.1 Increased Emphasis on Business Processes

Issue: Foresight studies suggest that the competitiveness of manufacturing companies will in future depend much more upon the effectiveness of business processes (see Annex 1): from the process of product definition through to the process of product delivery. Reviews of international best practice show that there is often far greater scope for improvement than firms realise. All firms must learn that changes which optimise processes rather than functions can take them to world-class performance with improved market share and improved profitability. However, although there are methods which lead to improvement - and may require radical change - there is no simple universal solution. Thus many companies hesitate and will wait until others have made the changes; sometimes unaware that competent competitors may beat them to it.

The key challenge is to develop commitment, plans and actions for rapid business process improvement in all manufacturing and production companies.

Objective: Those who support manufacturing, whether in business, education, research or government must help industry implement competitive business processes. Frequently this will require a number of disciplines to work together. Process mapping, modelling, benchmarking, analysis, simplification, integration and related skills must be improved and then competently applied. The company objective will be to bring about changes that combine and improve technical, business, human and organisational effectiveness. The best processes will be rapid, efficient, integrated, measured and controlled. Every process will add value. Organisations and resources supporting the processes will be shaped and trained to achieve continually higher levels of performance. The national objective will be to raise standards in many thousands of companies up to those of the best internationally competitive firms.

Approach: Industry must set the specific objectives, support the analysis and make the necessary changes. However it must also work wherever possible with a wider community who can systematically

study the full range of issues, examine best practices elsewhere and ensure that through research and education, the improvement process will continue. There is a pressing need to develop and disseminate information on the best business process practices, and how to introduce them. Those involved in research, education and training must rapidly build skills and most importantly, partnerships with industry.

Specific actions are necessary in three areas:

Research - One serious nationally co-ordinated research programme must oversee, integrate and set goals for business process research. All research programmes involving the science and technology base and industry must use business process disciplines. Many more nationally supported research programmes must have activities leading to business process improvement in industry and its supporting infrastructure. Objectives set for the Innovative Manufacturing Initiative must become exemplars of future practice. [21] .

- (Action must be taken by the Research Councils - particularly EPSRC and ESRC - with Higher Education Institutions (IEIs) and Industry.)

Note: Business process collaboration between industry and academe will take time to develop. Industrial staff with general management skills, rather than specialists alone, will need to co-operate with HEIs. Furthermore, academics will be competing with business process management consultancies, for example, to gain the time and attention of industrialists.

Implementation - There must be an outreach programme to ensure that new business process techniques are used in depth by companies and manufacturers.

- (Action must be led by Department of Trade and Industry (DTI), CBI with Trade Associations, Business Links, TECs and other bodies. The DTI must evaluate progress and lead or advise future changes.)

Education and Training - At a much earlier stage than today, students must understand the concept of manufacturing as a series of business processes rather than functional organisations.

- (Action must be led by Department of Education (DFE), Department of Employment (DEMP), Department of Trade and Industry (DTI), with education and training establishments and other bodies.)

5.1.2 Technology Priorities for Competitive Manufacturing and Production

The Panel has identified key generic technologies to support and improve competitiveness for the wide range of manufacturing and production businesses in the UK. In many cases, the technology requirements exist world-wide and large markets will become available to those who develop the necessary skills. This section highlights topics which are key priorities for nationally funded research and development. Competence in these fields will ensure that the UK obtains the best possible benefit from products with technological origins in the national science base.

Multi-discipline Projects: Manufacturing competitiveness will continue to depend upon a company's ability to combine a number of skills and technologies. (For example, materials technologists working

with process control technologists to provide consistent higher quality finished materials irrespective of raw material quality.) Thus, in addition to the continuing need for excellence in specialist disciplines, it is important to develop systems skills to link and enhance the work of specialists.

Very many new products and processes result from the combination of different disciplines. This combination may involve technical skills alone, but increasingly must involve those with a greater knowledge of human factors, sociology, economics or a multitude of disciplines which give a stronger market or user influence. (This could lead, for example, to the design of products capable of rapid customisation near the point-of-sale to match the needs of each specific market.)

Multi-discipline R & D projects must be encouraged in education, research and industry. The Research Councils must work with HEIs to promote multidiscipline projects which overcome departmental or other barriers to co-operation.

Process Plant Technology: Looking ahead, plant and equipment must meet new and demanding criteria. Competitive pressures are driving requirements for cost reduction, cycle-time reduction, yield and quality improvements, and lower energy or material costs. Many processes must have the flexibility to cope with greater product variety or throughput variation. Reliability must be improved, however plants will also need automated diagnostics and intelligent controls to compensate for failure or degradation. Maintenance must be rapid and automated where possible. Greater attention must be given to human factors - including health and safety. Plant must meet increasing environmental demands.

A range of research and development activities must improve manufacturing and production methods, plant and equipment. Whilst advanced automation systems must be developed to improve existing processes, it is also necessary to develop novel processes that greatly reduce the number of stages, complexity or cost. Improved integration must be achieved between the systems that support business processes and the controls that support production processes.

Plant and process equipment manufacturers must be encouraged to look at emerging product technologies, in the bio-sciences for example, and seek opportunities to develop production scale plant at the earliest opportunity in the product life-cycle.

Sensors and Controls: This will continue to be a priority area. General sensor needs include non-invasive methods, and specific needs include vision systems, improved chemical and biological measurements and sensors which replicate human senses such as taste, smell and touch. Control systems must work with increasingly complex plant, and must have greater degrees of autonomy and intelligence. Remote control will often be necessary.

Modelling, Simulation and Visualisation: New methods must be developed for the analysis, modelling and simulation of products and processes. Accurate and reliable design and simulation tools will greatly reduce the time and cost of product and process development, and are a key future need. Challenges include the modelling of complex and interconnected processes. Examples include plant simulations to analyse and minimise material use, energy use or waste. Other examples arise in forecasting and a wide variety of other business processes. Simulation and visualisation have many applications in the manufacturing enterprise, but will become increasingly important for customer use. Systems must be developed to allow customers to interact with intelligent product design systems that help them select their own preferred combination of product features. Furthermore, these customer interfaces must integrate with the manufacturing process - either to help the manufacturer learn more

about customer needs or even to commence the manufacturing activities.

Materials Processes: New materials, and particularly new materials processes are necessary for the future success of many manufacturing businesses (detailed studies have been made by the Materials Sector Foresight Panel). Specific points raised in the Manufacturing Sector Panel's study include, for example, the requirement that materials and processes must economically meet the growing demands for environmental compatibility. Process attributes include low cost, low energy, low waste, rapidity and flexibility. Finishing operations should be minimised, by 'near-net-shape forming' for example (which is a technique to allow high tolerance casting and avoids final machining operations). Materials must be suitable for efficient disposal or re-use at the end of their primary application.

Information Technology and Communications: These systems must provide an effective service to manufacturing and are potentially powerful competitive tools. They must support well designed business processes. System compatibility, open standards and upgrade paths must allow for increasing levels of electronics and software capability, and must provide increasing levels of business performance. Robust methods of handling the bulk complexity and uncertainty of information must be developed. There are many important issues and requirements in this field; however, the emphasis must be on creating systems which enable, support or enhance efficient and integrated business processes.

- (Actions in all the above areas must be taken by OST, Higher Education Funding Council (HEFC), Research Councils in association with industry, Research and Technology Organisations (RTOs) and DTI to ensure that the topics gain research emphasis. International benchmarking must be performed to ensure that the UK has adequate skills to underpin the necessary improvements in competitiveness and the subsequent growth of its manufacturing base.)

In addition to its selection of technology priorities, the Panel highlights the following key issues :

Research and Development

Through its consultations, the Panel has found great enthusiasm for closer alignment between the science and technology base and industry, provided that an adequate level of basic research continues. The Panel recommends that basic research must be retained at a sufficient level across the widest field (irrespective of national priority areas) to allow the UK to be fully aware of emerging and potentially influential work elsewhere. The science and technology base must then assist industry become an intelligent customer in cases where it needs to source technology externally.

- (Action - OST and Research Councils.)

Manufacturers must be encouraged and educated to improve their technology management disciplines. One of the benefits of a disciplined approach would be the easier quantification by the science and technology base of manufacturers' priorities.

- (Action - Industry in association with HEIs.)

The growing influence and importance of international business strengthen the need for those in the UK to fully engage in international research and development programmes. The EU's Framework 1V Programme has many topics that will lead to improved manufacturing and production technology.

Global programmes such as the IMS (Intelligent Manufacturing Systems) initiative must also gain UK support. [19,20].

- (Action - Industry, OST and DTI.)

Improved Industry Links with Academe

Co-operation between academia and industry must be extended. To achieve this, all parties must see reward for their endeavours. Academic departments and staff must gain recognition for their work with industry, and the Research Assessment Exercise (RAE) must recognise its importance. Changes must be made to the assessment criteria of the RAE. (see 4. 1.3)

- (Action - HEFC and Research Councils.)

5.1.3 Improvements Through Education and Training

There are three key requirements. The first is for an improved image and public understanding of manufacturing to increase its attractiveness to the most able students. The second involves specific educational needs to improve the effectiveness of those entering manufacturing. The third is for new methods to give continuing education and training to those in industry.

Improved Image and Understanding: Society must come to understand and support competitive manufacturing as a cornerstone of national prosperity. Manufacturing must be seen as a worthy, exciting, challenging and rewarding career for talented individuals. Whilst firms must do more to promote their image, it is also necessary for manufacturers and educators to work together and promote a wider awareness of industry. More topics in the curriculum must be presented in a business or industrial context. Technology must be firmly embedded in school curricula and supported by local firms. Educators and industrialists must jointly develop appropriate teaching material and must improve teachers' knowledge of manufacturing industry. Educators must inspire youngsters with the excitement of technology and manufacturing.

- (Action - Professional Institutions, Engineering Council, Trade Associations, DFEs and HEIs.)

Skill Needs: Education must emphasise the development of interpersonal skills, communication skills, problem-solving and teamwork skills, and the need for versatility. Business process awareness must be improved for technical and other specialists (not just business awareness). All students must learn of the rapid and international pace of change (foresight) and recognise that some knowledge has a limited life. They must learn how to continue their studies as their careers develop. They must enter industry with an excellent educational foundation and a framework on which they can build future material. Competent managers in industry must guide and support this continuing process.

- (Action - DFEs, all Education and Training Establishments and Industry.)

Continuing Education: One of the inhibitors of continuing education and training is the time availability of people in industry - particularly those developing managerial roles. Carefully focused education and training must be brought to the individual or the workplace through networks (electronic and local) involving external educational establishments. These new and more effective training schemes must be enhanced by the growing networks of telecommunication and IT

infrastructures and multimedia technologies. Similarly, on-line assistance services must be developed to bring instant help on technical, market, commercial and other business topics.

- (Action - HEIs, Industry and Service Providers.)

5.1.4 Extended Vision for Manufacturing and Production Businesses

Issue: Foresight studies suggest that the world market for manufactures will continue to grow for the foreseeable future. However, customer requirements are rapidly changing in many countries. So too is the intensity and international nature of competition. More must be done to help the UK manufacturing base understand the changes and benefit from the opportunities.

Objective: Manufacturers must continue to improve their knowledge of markets, customers, competitors and technology. They must review the drivers of change and develop the vision, plans, resources and determination to benefit from these changes. Furthermore, they must be creative and innovative to introduce competitive products and processes. There must be an 'innovation culture' such that firms feel the pressure from society, customers and shareholders to innovate if they wish to survive and thrive.

Approach: More foresight processes must be used in industry, and an awareness of foresight methods must be developed throughout the educational system. Youngsters must enter manufacturing industry with an ability to understand and debate the factors that influence future business success. Creative abilities must be encouraged and developed through education, and innovation must be encouraged and developed in industry.

The following three communities must increase their attention to this need and must co-operate to develop activities which promote foresight thinking, and the development of vision, creativity and innovation:

Education: The young must be given an opportunity to think about the future but in a structured and guided way which enables them to discuss and evaluate the issues and the future possibilities. Elements from the present foresight process could be developed into such a programme.

- (Action - DFE, OST, Industry.)

Industry: Companies must regularly examine the drivers of change that influence their long term future. Evidence from this first cycle of the Foresight Programme suggests that some companies do this very well, but the vast majority do not. Improved vision must be supported by increases in creativity and innovation.

- (Action - DTI with CBI, Trade Associations, Professional Institutions.)

Government and Academe: Those who acquire information or study trends and scenarios must assist industry improve its knowledge of international markets and the drivers of change. Those who study and improve creativity and innovation must also assist industry.

- (Action - DTI with CBI, through Business Links, competitiveness clubs, etc.)

5.1.5 Improved Communications and Support Networks

Issue: Foresight studies show that future business success requires improved communication between people and between companies. These communication requirements are driven by the need for supply chain integration, and the need for business alliances. Furthermore, manufacturers need improved links to their markets and customers, and better links to sources of information, assistance and education. Smaller networks will support local groups whereas larger networks will have international coverage and will offer multiple value-adding services to manufacturers. Telecommunications and IT currently support many basic services - however UK based manufacturers must outline their future needs and help service providers create additional networks and services. Examples of requirements outlined in this study include on-line technical assistance, interactive systems to help customers, 'virtual enterprise' group working, education and training in the workplace, and teleworking.

Objective: The primary aim is to develop value-adding services for manufacturers.

Approach: Industry, trade associations and professional institutions, service providers and government must work together to identify communication needs and benefits. They must develop the necessary infrastructure. Service providers must employ best practice techniques to make the service effective and 'user-friendly'. Many people must be educated about the existence and value of these networks.

Specific actions are necessary in two areas:

Open Electronic Networking: Many more firms must use electronic communication eg. EDI - Electronic Data Interchange

- (Action - DTI, CCTA, CBI, and Trade Associations to promote.)

International Networks and 'Information Superhighway': Wide networks that are both open and secure, must be developed as the backbone of future networks and services.

5.1.6 National Infrastructure for Improved Competitiveness

Issue: The increasing international mobility of production facilities, technology, finance, and to some extent - people, suggests that the UK will have to compete harder to retain existing industries and attract new industries.

Objective: The UK must provide a competitive base for a thriving manufacturing industry, and must therefore have an excellent infrastructure. National reinforcement of manufacturing requires education to the highest international standards, a world-class science base with emphasis on local exploitation, and effective communications and transportation systems. Monetary policies, ownership policies, and trade policies must be fair and must be developed through continuous dialogue with industry. There is a need for national economic strength with low interest rates, low inflation and stable exchange rates.

Approach: Specific recommendations include the need to continue the deregulation initiative and help industry avoid excessive future regulation particularly EU legislation. Government departments have an important role in promoting best practice. They are an excellent catalyst for the creation of networks of support. They must continue to provide a wide range of services, including international information

and export assistance to manufacturers. They must continue to develop and support programmes which connect the science and technology base with industry - LINK, for example. They must continue to develop and support programmes which connect individuals in education and the science base with industry - The Teaching Company Scheme, for example.

- (Actions - OST and DTI in association with Industry.)

Geographically, the UK occupies a peripheral position on the edge of our main market area of Europe. Transportation and communications must be rapid and efficient to win customers and develop the UK image as a 'local' supplier throughout Europe.

- (Action - Department of Transport.)

Finance for industry is a key to future success and although it is primarily in the private domain, the government has a large influence. This influence must be reviewed by government against the evidence of poor UK productivity and insufficient long-term investment compared with other industrial nations*, and against an economic scenario which shows the dependence of future national success upon increased UK manufacturing strength. Measures must be taken to encourage firms to invest in the longer term as well as in near term productivity improvements.

- (Action - Treasury, with DTI, to consider again why, in the UK, there persists a higher level of distribution of dividends and a lower level of re investment, particularly in R & D, than in comparable OECD countries and whether changes can be made to remedy this, for example through personal incentives for savings.)
- (Action - Government must provide a consistent dialogue with industry and a consistent level of support to improve competitiveness taking action where market forces seem inadequate.)

The execution and timely diffusion of the most important recommendations from all Foresight Panels may call for a different overall allocation of resources between consumption and investment, and a longer term outlook from financing institutions.

5.2 IMPLEMENTATION PROCESS FOR TECHNOLOGY FORESIGHT RECOMMENDATIONS

This report should initially be disseminated to all those involved in the Panel's consultations, including the expert pool, organisations and individuals who kindly contributed information and assistance. The report should also be sent to representatives of organisations and institutions capable of implementing the Panel's recommendations. The immediate objective will be to identify any issues requiring clarification. The Panel must then discuss with the principal organisations how it can assist the development and implementation of activities resulting from its recommendations.

* Note: The ratio offered capital expenditure to GDP in 1993 was 15.5% in the UK, compared with 19.6% across the EU and 31.2% in Japan. See Section 31 also.

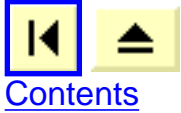
Wider dissemination of the report to companies should be made by trade associations, professional bodies and the DTI as part of their ongoing efforts to improve awareness and competitiveness of industry. Similarly, dissemination in government, education and nationally supported research should be done through existing channels.

The panel recommend that a record must be kept of comments and advice from the recipients of the report. The panel will analyse this record and recommend any necessary changes of emphasis or methodology for subsequent iterations of the Foresight Programme.

The panel should stay in existence to be a centre of knowledge or excellence and hence oversee and co-ordinate the wide ranging work of many bodies on Business Process research and implementation. DTI, and other sponsoring Departments, must take account of shorter term implications of the Technology Foresight priority areas in their technology acquisition and creation programmes and in their innovation programme for improved business processes (with CBI) and create a dialogue with their industries on the technology consensus areas.



Progress Through Partnership: 9 Manufacturing, Production and Business Processes



6 CONCLUSIONS

The manufacturing and production sector of the UK economy has been the subject of many studies in recent years. The Foresight Programme has taken a longer look forward than many other studies have done. Its objectives were to examine technological and other factors that can be changed to improve competitiveness, wealth creation and the quality of life. The studies have identified market opportunities as well as internal improvements for manufacturers and their supporting infrastructure.

The panel of 25 members from industry, academe and government has worked successfully as a team. They have been well supported by external organisations and individuals who have contributed much valuable information and assistance. The Foresight process has worked satisfactorily, although a number of enhancements should be incorporated in the next iteration. The scope of the study was particularly broad and the Foresight process applied by the panel has enabled it to keep a wide perspective whilst using prioritisation criteria to select areas for greater analysis.

Despite good performance in a few manufacturing sectors, UK-based manufacturing as a whole has not performed as well as that in other industrialised nations in recent years. Productivity has improved, but is still below achievements elsewhere. Export volume has increased, but has not regained its earlier share of world markets. Full-time employment in manufacturing is declining, and has halved in the last 25 years. However, manufacturers account for 60% of UK exports and consequently success in the manufacturing sector of the economy is vital to future national prosperity.

The panel has reviewed trends, future scenarios and has examined the more influential drivers of change. These include internationalisation and the growth of new markets and competitors, consumerism, competitiveness through improved business processes and people, emerging technologies, concern for the environment, improving worldwide education standards and increasing regulation.

Future success for UK-based manufacturers in this rapidly changing world market requires improved business processes, improved technology and additional support from the national infrastructure. The objectives are to increase productivity, to increase exports and satisfy more of the domestic market, to innovate, to improve product and process technologies, to improve the effectiveness of business processes, to improve teamwork, skills and organisational effectiveness, and to integrate and accelerate design and production processes.

The key recommendations include the implementation of improved business processes through collaboration between those in industry, education and research. New emphasis in education must develop a wider understanding of manufacturing industry. Curricula must have industrial relevance. Education must help students develop interpersonal skills, communication skills, problem-solving and teamwork skills. Business awareness, and business process awareness must be improved. New methods must be developed to assist with continuing education, particularly by using local networks and IT to bring training to individuals in the workplace. Many in manufacturing and production

industry must improve their knowledge of future opportunities and issues (foresight), and must be assisted to gain better market information, to develop best practices and to become more innovative. Networks must be developed to support alliances between companies, education, research, government and others regionally, nationally and internationally.

Technology emphasis must include multi-discipline activities and related systems skills. Process plant and equipment must be improved to reduce costs whilst also meeting new environmental requirements. Sensors and controls are a related key area for continuing improvement. New methods must be developed to improve modelling and simulation of products, production processes and business processes. Materials and material processes underpin much of manufacturing and production, and emphasis must be given to low cost, low waste, and environmentally compatible materials and processes. Information Technology can greatly enhance a wide range of technical and business processes. System compatibility, connectivity and continuous upgrade paths must accommodate rapidly the growing IT hardware and software developments. The national science and technology base must work in closer co-operation with industry and must maintain excellence in basic research. Those in academe must gain recognition for partnerships with industry, and the Research Assessment Exercise must change to reflect the importance of this work.

The government must ensure that the UK is a competitive base for a thriving manufacturing and production industry. Necessary infrastructures include education to the highest international standards, a world-class science and technology base, and effective communication and transportation systems. The government must continue its deregulation initiative, and press for minimal and sensible EU regulation. The government must support the creation and operation of networks of support to industry. It must also support programmes which connect the science and technology base to industry, such as LINK, and programmes which improve the industrial experience of individuals - The Teaching Company Scheme, for example. Finance for industry is a crucial requirement if improvements are to be made by firms. The government and others supporting industry must take measures to encourage and help firms to invest in the longer term.

The panel has recommended a number of specific actions which will lead to the improvements necessary to meet the panel's Foresight objectives. The panel will remain in existence to assist the responsible bodies review the issues and implement necessary changes.

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Reference index numbers are listed at the end of each relevant paragraph in the main text.

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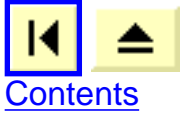
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Progress Through Partnership: 9 Manufacturing, Production and Business Processes



ANNEX 1 BUSINESS PROCESSES

Dr J Parnaby, Lucas plc The implementation of true business process organisational architectures in manufacturing industry, outside of Japan is very much in its infancy. Very limited experience of practical operation exists, many companies are not aware of the concepts and few have even considered how to balance the need for excellence of core functional and technological competencies with effectiveness of processes.

The best way to visualise a business process is to consider the group of skills and competencies which have to be brought together to develop or deliver a product or service. Such a group is a natural process group and is implemented physically in the form of a cross functional team. It is supported by means for maintaining sharpness of functional skills and represents the basic building block of a highly effective organisation. It also operates and represents a practical matrix concept. The alternative of a traditional functional organisation in which concentrated single-functional skill groups reside in separate departments, fragments the natural process work flow and information flow. Such traditional arrangements are now becoming uncompetitive in a global marketplace. They take longer to carry out tasks, have higher costs, produce a lower quality performance and create very narrowly focused people who then become vulnerable to change.

There are many obstacles to the creation of business process organisation structures, not least of which is the resistance of vested interests and culture, the latter being changeable through new developments in education and training.

Current approaches to business process organisation design are primarily ad-hoc and often superficial. A systems engineering approach is essential even for a relatively small process module of an organisation. A body of knowledge is required to support the implementation of business process concepts.

Tools and techniques, sharpened by semi-empirical application, must be developed for the first phase of design to create the basic business process architecture. These must be supported by a further increasingly detailed second phase of development of methodologies for designing and supporting controls, team working practices, continuous improvement and system maintenance capabilities. Finally best practice and competitiveness studies must be continually carried out to determine measures of performance which cascade in increasing detail from those which apply at the top of the organisation across all business processes to those which are used to drive the performance of every process module, cell or team. There is typically a set of five generic measures of performance:

- Quality, Customer Satisfaction, Financial, Process Lead Time or Delivery Time and Level of Work in Progress.

Some processes in manufacturing businesses depend heavily on the development of technological

materials-forming processes and the associated machines and electronic control systems to carry out the processes and to test the products. There is a continuing need for R&D here.

A great deal of multi-disciplinary R&D is required therefore, over the next ten years to fill the gaps in methods, tools and techniques for design, practical operation and monitoring outlined above as well as for the development of education and training courses. Any suggestion that such work is not essential or is not intellectually demanding and complex, cannot be defended.

SUPPORTING FRAMEWORKS FOR DEVELOPMENT

To guide a careful, systematic and structured approach for defining necessary R&D topics, logical frameworks are needed which also ensure a systems approach.

A BUSINESS PROCESS MODEL

When viewed from the highest level there are only three core value-adding processes in a manufacturing business:

1. The Development or Innovation Process.
2. The Operational Delivery Process.
3. The Support Operations Process.

and to create these there is the need for a temporary further project managed process:

4. The Change Process.

The later becomes eventually subsumed by evolution as a Kaizen or continuous improvement process within the first three processes.

It is necessary for practical application to sub-divide and add more manageable shape to the first three processes and to recognise also that in large organisations these are implemented in the form of modules or process cells linked by matching inputs and outputs and customer supplier relationships within a framework of measures of performance.

A typical sub-divided set of processes is given in Table 1.1.

Table 1.1 - Business process framework

1. The Strategic Planning Process.
2. The New Product Introduction Process incorporating the Marketing Process, Research, Development, Design, Design for Manufacture, Design of the Manufacturing System.
- 3.

4. The Sales or Order Winning Process.
5. The Materials Flow Logistics Management, Manufacturing Operations and Delivery Process.
6. The Supply Chain Process.
7. The Distribution Process.
8. The Financial Control Process.
9. The Debtors Control Process.
10. The Creditor Control Process.
11. The Maintenance Process.
12. The Learning Support Process.
13. The Technology Support Process.
14. The Change Management Process.
15. The Procurement Process.

All Processes must be supported by integral quality support systems, change control systems, continuous improvement Kaizen activities and planning systems.

A six element framework for identifying and specifying R&D tasks in an integrated way is given in Table 1.2.

As each process module is created organisationally and the management systems are developed, it is necessary to treat each module as a system within itself and develop the necessary supporting elements. An illustration for a manufacturing cell process is given in Figure 1.1 which applies equally to an office based process cell.

Table 1.2 - Identification of R & D areas for each business process

1. Organisation of the business process for teamwork.
2. Development of process analysis and design tools.
3. Development of support tools, techniques and subsystem infrastructure for process operation.
5. Control and monitoring systems development to meet benchmarks and measures of performance.
6. The integration of process focused IT and its linking to shared infrastructure IT.

THE NEXT FIVE YEARS

There will be a wide ranging acceptance by industry of the need to move towards more competitive process based organisations and once the trial and error phase with its frustrations has been reached, the demand for a much more professional approach will grow. The academic, research and industrial community must therefore, in parallel, be developing and testing the necessary education and training support as well as developing the supporting body of knowledge to cover all areas of need in Table 1.2. As increasingly mature forms of business process organisations evolve, the demand for refinement to maintain competitiveness will grow, so stimulating more detailed and sophisticated research and development activity.

The skills required for such R&D range from social science to materials science and systems engineering i.e., truly multi and inter-disciplinary. Well structured programmes will be required with high quality project management and so far as the industrial and academic research community is concerned, there will truly be something in it for everyone.

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Progress Through Partnership: 9 Manufacturing, Production and Business Processes



ANNEX 2 REPORT ON THE DELPHI QUESTIONNAIRES

Nigel Gilbert, *University of Surrey*

SUMMARY

The responses from the second round of the Delphi questionnaires for the Manufacturing Panel have been examined. Few respondents appear to have come from a typical SME background. Almost all respondents were male.

The topics most highly rated for their potential for wealth creation by the respondents taken as a whole were overwhelmingly associated with advances in business processes. However, respondents from academic backgrounds and those who counted themselves as knowledgeable or expert in the topics ranked a greater number of technological topics among those considered most promising for wealth creation.

The UK was judged overall to be neither leading nor lagging in its scientific capability. Those topics where it was considered the UK had a lead over the rest of the world were in general areas where there have been recent Research Council or European Union research initiatives. A number of topics that will make their main impact after 2005 and have a high potential for wealth creation and for enhancing the quality of life can be identified from the data (see Figure 2.10 and Figure 2.11). These are topics where there is still time for research and development to be encouraged in the UK.

DATA AND METHODS

A data file was obtained from Business and Market Research plc containing the responses from the Manufacturing Panel second round Delphi questionnaire^[1]. There were 278 respondents.

A variety of analyses, reported below, were carried out using the statistical analysis package, SPSS. SPSS was also used to find the means of the replies for each topic, averaged over all the various subsets of respondents, and these means were examined by another statistical package, JMP.

[1] The data file was first read into SPSS, which noted that there were 6 duplicate records (questionnaire lines that had been entered twice), and that the experience of one respondent had been consistently coded '-', an illegal code.

CHARACTERISTICS OF THE RESPONDENTS

Almost all of the respondents were male (97% of those who stated; 18% did not specify their sex) and most were aged between 40 and 60 (61%).

36 (15%) indicated that they were from a company with less than 250 employees. However a little less than one third of these (10) also indicated that their experience was in corporate strategy, suggesting that they were most probably independent consultants, rather than employees of small or medium sized manufacturers. The same may be true of the five whose experience was in research management (see Figure 2.1). Because this seems to suggest that those identifying themselves as coming from a company with less than 250 employees are far from typical members of SMEs, no analyses of data from this sub-group have been done.

Of those working for an organisation with 250 or more employees, a quarter were academics, 17% were concerned with operations and production, and 12% with corporate strategy.

Experience	Less than 250 employees	Other
Corporate strategy	28%	12%
Marketing	14%	7%
Production	8%	17%
Academic	3%	25%
Industrial research	22%	22%
Research management	14%	12%
Other	11%	6%
Number of respondents (36)		(189)

Figure 2.1 Respondents' experience by size of organisation

RANKING OF TOPICS

Leading wealth creators

Figure 2.2 shows the top quartile of topics as judged by respondents' mean preception of their potential impact on wealth creation.

Rank	Topic	Mean score on impact	Number of respondents
1	Q69 Flexible teams	2.68	235
2	Q27 Concurrent engineering	2.67	230
3	Q68 Methods to promote creativity	2.67	230
4	Q33 24 hour plants	2.65	224
5	Q32 Rapid prototyping	2.64	228
6	Q35 Real-time efficiency measures	2.64	222
7	Q16 Self-compensating processes	2.63	224
8	Q65 Computer-based training	2.61	225
9	Q29 Network of experts	2.59	226
10	Q47 Market info networks	2.59	229
11	Q52 Process simulation & modelling	2.59	227
12	Q34 Halve no. of process steps	2.58	214

13	Q61 SME Alliances	2.58	221
14	Q4 Low cost material processes	2.56	218
15	Q31 Reliable CAD	2.56	226
16	Q48 Strategic use of STEEP	2.54	228
17	Q66 On-line assistance	2.53	227
18	Q50 Whole enterprise modelling	2.52	232
19	Q7 Close tolerance casting	2.51	215
20	Q3 Molecular miniaturisation	2.50	223
21	Q51 Real time reporting of performance	2.50	226

Figure 2.2 Top rated topics for wealth creation potential

It is noticeable that item 14 (Low cost material processes) is the first that clearly involves technological advances, the earlier ones being associated more with advances in and adoption of business processes.

Figure 2.3 shows the rank order taken only from those who identified themselves as academics. The list is quite different, in particular having a much more conventionally technological flavour to it. The academics are in general less inclined to attribute wealth creation capability to any of the topics, and while the top few topics are credited as highly as the overall sample, the remainder are not very highly rated.

Rank	Topic	Mean score on impact on walth creation	number of respondents
1	Q29 Network of experts	2.73	41
2	Q31 Reliable CAD	2.69	42
3	Q27 Concurrent engineering	2.68	41
4	Q81 Tools to highlight standards in design	2.67	18
5	Q66 On-line assistance	2.63	40
6	Q44 Commsd to integrate SME's	2.61	38
7	Q13 Automated vision for process measurements	2.60	40
8	Q47 Data networks for info. on markets	2.56	39
9	Q57 Modelling to minimise energy use	2.56	39
10	Q20 Integrated IT for training etc.	2.46	39
11	Q35 Real-time efficiency measures	2.46	41
12	Q65 Computer aided learning at workplace	2.46	39
13	Q3 Molecular miniaturisation	2.45	38
14	Q32 Rapid prototyping	2.45	40
15	Q16 Self-compensating processes	2.44	41
16	Q17 Self-organising facility for low vol. products	2.36	39

17	Q22 Automated assembly of complex products	2.36	39
18	Q58 Modelling to minimise waste	2.36	39

Figure 2.3 Top topics for wealth creation potential as rated by academics

1	Q3 Molecular miniaturisation	3.61	18
2	Q7 Close tolerance casting	3.57	37
3	Q61 SME Alliances	3.56	63
4	Q44 Comms to integrate SME's	3.51	49
5	Q68 Methods to promote creativity	3.50	78
6	Q5 High effects coatings	3.47	40
7	Q34 Halve no. of process steps	3.47	53
8	Q17 Self-organising facility for low vol. products	3.46	39
9	Q21 Integrated process control and business processes	3.46	46
10	Q69 Flexible teams	3.45	80
11	Q4 Low cost material processes	3.43	35
12	Q9 Sub-micron processing	3.42	33
13	Q14 Sensor-fusion techniques	3.40	25
14	Q22 Automated assembly of complex products	3.39	38
15	Q32 Rapid prototyping	3.39	71
16	Q58 Modelling to minimise waste products	3.39	23
17	Q45 Info. systems to support whole supply chain	3.38	50
18	Q81 Tools to highlight areas where standards influence design	3.38	16
19	Q48 Strategic use of STEEP	3.37	51
20	Q29 IT support for distributed experts	3.36	74
21	Q59 Reconfigurable manufacturing cells	3.36	47
22	Q50 Computer-based business modelling systems	3.36	59
23	Q19 Self-repairing manufacturing systems	3.35	17

Figure 2.4 is the ranking considering only the replies of those who counted themselves as either knowledgeable or expert on the topics (i.e. degree of expertise of 4 or 5). The rank order is substantially different from both the overall ranking and the ranking of academics, with several topics (e.g. Q7, Q5, Q17, Q21, Q9, Q14) appearing high in the experts' ranking, but low or not at all in the other rankings. The experts give the topics, on average, much higher ratings for their impact on wealth creation than the academics[2].

Areas where the UK is leading or lagging behind

On the whole, the UK is judged to be an average performer in comparison with other countries when it comes to its current scientific and technological capability. On a scale from 1 (the UK is a leading edge performer) to 3 (is lagging behind), the distribution of means of responses amongst the topics is as shown in Figure 2.5. The median is almost exactly 2.

[2] There is a high correlation between respondents' perceived expertise and their judgements about the potential of topics to create wealth - those who counted themselves as experts on a topic were inclined to judge that topic as having a high potential for wealth creation.

The areas where the UK is judged to be an above average performer in scientific capability are shown in Figure 2.6. It is interesting that a high proportion of these topics have been the subject of recent Research Council and EU special programmes (e.g. unmanned transport, recycling and reuse of components, and language translation software).

Rank	Topic	Mean score on scientific capability	Number of respondents
1	Q23 High speed unmanned transport	2.25	110
2	Q56 Production and scheduling software	2.22	117
3	Q40 Return of components for re-use or recycling	2.21	152
4	Q24 Distributed manufacturing systems	2.16	120
5	Q38 Re-use of components	2.15	127
6	Q19 Self-repairing manufacturing systems	2.14	111
7	Q78 Language translation software	2.14	<123/td>

Figure 2.6 Top rated topics for the UK's current scientific capability

Figure 2.7 shows the ranking as judged by 'experts', i.e. those who said that they were knowledgeable or expert on the topic. The list is similar to that for all the respondents, except that topics Q3 (Molecular miniaturisation) and Q73 (Universal IPR) enter at positions 5 and 6.

Rank	Topic	Mean score on scientific capability	Number of respondents
1	Q40 Return of components for re-use or recycling	2.23	<31/td>
2	Q56 Production and scheduling software	2.22	23
3	Q38 Re-use of components	2.16	25
4	Q23 High speed unmanned transport	2.12	8
5	Q3 Molecular miniaturisation	2.11	18
6	Q73 Universal IPR	2.09	33
7	Q67 Remote control of production facilities	2.06	32
8	Q81 Tools to highlight areas where standards influence design	2.06	16

Figure 2.7 Top rated topics for the UK's current scientific capability, as judged by experts

Examining opinions about the UK's capacity to produce in the various areas shows that the mean is slightly higher (2.25) and the spread of opinions somewhat less peaked. The top topics are shown in Figure 2.8.

1 Q23 High speed unmanned transport	2.36	111
2 Q19 Self-repairing manufacturing systems	2.33	109
3 Q8 High temperature superconductors	2.31	126
4 Q3 Molecular miniaturisation	2.30	<148/ td>
5 Q56 Fully automated maintenance	2.30	116

Figure 2.8 Top rated topics in relation to current production capability

RELATIONSHIPS BETWEEN RESPONSES

In the following sections, topics are plotted to show the relationships between characteristics such as their capacity for wealth creation, period of occurrence and UK's capability in the area. In the plots, the period shown is the mean, over all respondents when coded on the scale: 1 = 1995 - 1999; 2 = 2000 - 2004; 3 = 2005 - 2009; 4 = 2010 - 2014; 5 = 2015 and beyond; 6 = Never. While the original question just asked respondents to rank the likely first occurrence into the (unequal) categories offered on the questionnaire, and coding the categories imposes a quantitative scale on the ranks, the resulting mean does give a rough impression of the relative timings suggested by the sample.

Potential for wealth creation and improving the quality of life are coded from 1 (harmful) to 4 (highly beneficial) and the UK's relative capabilities are coded from 1 (leading edge) to 3 (lagging behind).

Relationship between capacity for wealth creation and likely period of first occurrence

Figure 2.9 plots wealth creation potential against the likely first period of occurrence, as judged by those who considered themselves to be either knowledgeable or expert about the topic. Topics in the bottom half of the figure are likely to have a small impact on wealth creation, while topics on the left half (i.e. with period less than 2.0) are likely to come to maturity before the UK has had much opportunity to improve its position. The critical areas are those in the top right hand quadrant. The table below the Figure lists the topics in this quadrant.

Topic	Wealth creation score	Period
Q2 Intelligent materials	3.12	2.83
Q3 Molecular miniaturisation	3.61	2.78
Q8 High temperature superconductors	3.29	2.85
Q12 Chemical and biological measurement technologies	3.17	2.66
Q19 Self-repairing manufacturing systems	3.35	2.71
Q28 Image prototyping	3.02	2.85
Q30 Regulatory approval at design stage	3.09	3.30
Q56 Automated maintenance of production equipment	2.96	3.32

Q58 Modelling to minimise waste products	3.39	3.00
Q64 Support facilities for disabled and older workers	3.22	2.67
Q76 Supervisory IT systems	3.28	2.86
Q77 Voice systems in manufacture	3.00	2.76
Q79 International product description language	3.31	3.69

Figure 2.9 - Wealth creation potential versus likely first period of occurrence

Topic	Quality of life score	Period
Q1 Modelling systems to create ideal materials	2.79	2.55
Q3 Molecular miniaturisation	3.33	2.78
Q8 High temperature super conductors	3.07	2.85
Q12 Chemical and biological measurement technologies	3.10	2.66
Q19 Self-repairing manufacturing systems	2.82	2.71
Q23 Unmanned high speed transport	2.88	2.62
Q36 Zero waste recovery systems	3.44	2.89
Q37 Retrofitting waste recovery systems	3.44	2.89
Q38 Reuse by design	2.93	3.17
Q58 Modelling to minimise waste products	3.39	3.00
Q60 Remote control of complex plants	2.85	2.70
Q64 Support for older and disabled workers	3.22	2.67
Q77 Voice-activated systems in manufacturing	2.69	2.76

The topics listed are therefore those where it is anticipated that there will be at least ten years before widespread adoption or use, and where there is expected that there will be a substantial impact on wealth creation. They are all topics where technological advances are required and none of them are directly related to the implementation of business processes (compare the list in Figure 2.2).

Relationship between capacity for improving the quality of life and likely period of first occurrence

A similar analysis for topics expected to improve the quality of life is shown in Figure 2.10. Several of the topics occupying the upper quadrant on this plot are also to be found in the upper right quadrant of Figure 2.9. In addition, there are topics relating to recycling and re-use of components.

Relation between potential for wealth creation and the UK's innovative capacity

To advance the UK's prospects, it would be helpful if those topics that were identified as having the greatest potential for wealth creation were also those in which the UK's current innovative capability was highest. Figure 2.11 plots two variables and the table below shows the twelve topics with the highest scores on both. If it was desired to support those topics where the UK already has strength and which were likely to generate wealth, these are some of the areas to select.

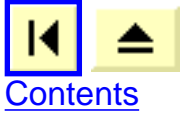
Topic	Innovative capability score	Wealth creation score
-------	-----------------------------	-----------------------

Q3 Molecular miniaturisation	2.06	3.61
Q9 Sub-micron processing	1.97	3.42
Q17 Self-organising production	2.03	3.46
Q42 Customers having interactive access to product information	2.00	3.24
Q43 Customers personalise products	2.00	3.26
Q48 IT supported STEEP Knowledge acquisition	2.00	3.37
Q50 Computer based modelling	1.98	3.36
Q58 Modelling to minimise waste products	2.00	3.39
Q59 Reconfigurable plant	2.00	3.36
Q64 Support for disabled and older workers	2.00	3.22
Q68 Techniques to promote creativity	1.99	3.50
Q69 Flexible teams	1.99	3.45

Figure 2.11 - Potential for wealth creation by the UK's innovative capability



Progress Through Partnership: 9 Manufacturing, Production and Business Processes



ANNEX 3. DELPHI QUESTIONNAIRE

SUB SECTOR NO.

TOPIC STATEMENT

Materials and Material Processing

- 1 Elucidation of information and modelling systems available to define or create the 'ideal' structural material with predicted performance for any given application, (e.g. new composites).
- 2 Improved production equipment performance through the widespread use of 'intelligent' materials capable of adapting to external stimuli.
- 3 Widespread exploitation of techniques using miniaturisation down to molecular level in products and processes.
- 4 Practical use of processes for the production of currently recognised materials by novel, low cost, undemanding methods (e.g. at ambient temperatures and pressures).
- 5 Widespread use of simple techniques for surface treatment of low cost base materials with high effect coating or films.
- 6 Widespread use of simple negligible-friction coating systems to reduce wear.
- 7 Widespread use of material processing methods which achieve close dimensional tolerance from casting, forging or pressing processes.
- 8 Practical use of high temperature superconductors in manufacturing processes or process equipment.
- 9 Practical use of low cost techniques of forming or processing materials with features in the sub-micron size range.

Measurement and Sensors

- 10 <-- missing -->
- 11 <-- missing -->
- 12 Widespread use of chemical and biological measurement technologies with valid analytical results and accuracies equivalent to those achieved in physical and engineering metrology.
- 13 Practical use of complex production equipment which relies upon automated vision and optical sensors for all process measurement.

14 Widespread use of sensor-fusion techniques to enhance the quality of measurements and to automatically diagnose sensor failure./td>

15 Significant use of production equipment with embedded intelligent sensors which monitor, predict and plan maintenance work.

Automated Production Processes

16 Practical use of production facilities with integrated measurement and control systems providing automatic self-compensation for the total process.

17 Practical use of modular, self-organising or reconfigurable production facility for continuous process of low volume/high variety products.

18 Practical use of automated solid model production equipment, capable of working with a variety of materials, and linked to development systems for rapid creation of small production batches (e.g. advanced stereolithography).

19 Practical use of self-repairing manufacturing systems linked to sophisticated self-diagnostic tools.

20 Widespread use of integrated IT provision to all operator based equipment to allow training, in addition to display of machine and product status information and automatic recording of information.

21 Practical examples of process plants with process control systems (technical drivers) totally integrated with business process systems (schedule, resource, cost and competitiveness drivers).

22 Practical use of assembly equipment for the manufacture of products with complex mechanical or electromechanical components.

Production Process Support Systems

23 Development of high speed, unmanned transport of components or materials between factories, companies and markets.

24 Widespread use of highly distributed manufacturing facilities allowing reduction of movement of people or goods to reduce the impact of transportation.

25 Move to greater concentration of related manufacturing activities into major conglomerations to reduce movement of people and goods.

26 Widespread use of high definition 3D video and related technologies for the remote monitoring of plant processes.

Integrated Engineering Processes

27 Widespread use of integrated information capture and communication systems throughout the enterprise allowing comprehensive concurrent design of product and process.

28 Practical use of image prototyping in place of solid prototypes (e.g. virtual realisation by hologram) as the only precursor to full scale production.

29 Comprehensive integrated IT support to support completion of a single project by a variety of experts in widely dispersed location all networked as a team to achieve the required objectives.

30 Design systems sophisticated to such a degree that regulatory approval can be obtained prior to commencement of production.

31 Practical use of computer-aided design systems which are totally reliable for a prescribed range of applications and have been validated by independent means.

32 Widespread use of rapid prototyping for product and process design.

Production Efficiency

33 Widespread adoption of 24 hour/7 day plant operation driven by need to achieve higher utilisation of facilities and improve service to customers.

34 The number of steps in manufacturing processes will reduce to half the current level (e.g. by near net-shape, or closer tolerance, or better catalyst systems).

35 Widespread use of efficiency measures for all manufacturing processes and with real time measurements available at the process location.

Environment and Waste Reduction

36 Development of a major production facility where careful process design has allowed manufacture to take place with zero waste emission from the site.

37 Widespread use of factory based elimination of all wastes from current plants by retrofitting recovery systems (e.g. water treatment, heavy metal extraction, CO₂.)

38 Practical application of re-use of all component parts of products by careful design of initial product and process.

39 Development of fully comprehensive, rigorous environmental life-cycle analysis to inform design and production and meet legislation.

40 Majority of products are returnable for recycling or reprocessing to original manufacture or specialist disposal company (to recover metals and plastics).

41 Knowledge of likely failure mechanisms (such as material degradation) is considered as part of product design and determines the policy for repair or recycling.

Customer Linkage and Supply Chains

42 Customers have interactive access to relevant product information at the time and location of their purchasing decision.

43 Customers design or specify a personalised product by interfacing with databases and expert design systems held by their suppliers or partners.

44 Intelligent communication systems enable Small/Medium Enterprises or individual specialists to effectively integrate their skills and knowledge with industrial partners of their choice to form a wealth creating business.

45 Practical realisation of fully integrated operating information systems to support the whole supply chain.

46 Widespread simulation of logistics and supply chains to optimise information and material flows.

47 Widespread use of data networks to capture information on markets, suppliers and competitors.

Strategic Management

48 Widespread use of electronically supported knowledge acquisition at the strategic level of the company to assess economic, political, social, environmental and technological influence on markets and on business strategy.

49 Practical use of business simulation techniques to make the strategic and operational decisions necessary to overtake 'world-class' competitors.

50 Practical use of computer-based business modelling systems which examine the whole enterprise and specify business systems which optimise process transactions and the use of people.

Operations

51 Practical use of real-time automated reporting of all key performance parameters in a business unit (e.g. resource, utilisation, quality, cost, schedule).

52 Widespread use of process simulation and modelling tools which accumulate experience and optimise operating performance.

53 Significant use of low cost electronic tagging of all components to give total knowledge of all inventory and materials in process.

54 Practical use of substantially improved automatic test methods for complex products (e.g. rapid test or non-destructive test).

55 Widespread use of production control and scheduling software with prediction capabilities and real-time links with machines or process equipment.

56 First realisation of factory with fully automated maintenance of production equipment.

57 Widespread use of modelling techniques which predict and minimise energy use in an entire facility.

58 Widespread use of modelling techniques which predict and minimise waste products from an entire facility.

- 59 Practical use of widely and rapidly reconfigurable manufacturing cells and plants for high volume products.
- 60 Practical use of remote control of complex plants in special locations (e.g. space, underground or underwater).
- 61 Most Small/Medium Enterprises create networks or alliances rather than develop all competencies within their own organisations.
- 62 Widespread replacement of mechanical fastening systems (e.g. nuts and bolts) in favour of adhesives or rapid assembly/disassembly methods).

Personnel and Training

- 63 Widespread use of on-line monitoring and feedback of individual performance to optimise use in the factory and assist with future training needs.
- 64 Widespread provision of specific support facilities on plants and equipment for disabled and older workers.
- 65 Widespread adoption of computer-aided learning and training systems at the workplace to continually raise employee skills.
- 66 Widespread use of IT for specialists to seek instant on-line assistance from industry-wide sources rather than refer to books or libraries.
- 67 Widespread use or remote control of production facilities (including teleworking) allowing staff a better environment to work in.
- 68 Widespread use by businesses of management and organisation techniques which are proven to promote creativity or productivity from groups of appropriate individuals.
- 69 Widespread use of flexible teams to organise multi-skilled employees.

Security

- 70 The cost of maintaining acceptable levels of physical and commercial security is double the percentage of its current cost in business.
- 71 Widespread use of systems providing total traceability of materials from constituent parts to final products for quality assurance/forgery/safety purpose (e.g. use of molecular tags).
- 72 Greatly increased protection of Intellectual Property Rights (IPR) to overcome concern caused by the ease of information access by competitors using international data highways.
- 73 Competition is determined more by timing and market access than by technology because IPR is universally available.

Information Technology

- 74 Widespread use of 'minimal' IT in discrete packages to support business processes which have been simplified.

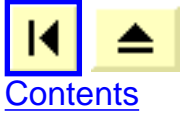
- 75 Practical use of standard packages of proven 'enterprise level' IT software which incorporates all features necessary for the operation of a large business.
- 76 Widespread use of 'supervisory IT' systems which monitor all business process transactions and provide advice on improvements.
- 77 Widespread use of voice-activated systems in manufacturing and business processes.
- 78 Practical use of foreign language translation software in business processes such as Electronic Data Interchange (EDI).
- 79 Adoption of a single internationally recognised and approved product description language across all industry sectors.

Standards and Regulations

- 80 Keeping in touch with standards and regulations absorbs over 20% of the time involved in product development.
- 81 Practical use of design tools which automatically highlight areas where standards or regulations influence a product design.
- 82 Practical application of international regulatory policy requiring standards for importers to cover not only the product but also manufacturing standards in the country of product origin.



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ANNEX 4 WORKSHOPS ON MANUFACTURING, PRODUCTION & BUSINESS PROCESSES

Five regional workshops were held at the following venues:

University of Strathclyde	(11th October; 35 attenders)
University of Warwick	(12th October; 26 attenders)
Belasis Business Centre, Teeside	(18th October; 19 attenders)
University of Bristol	(1st November; 21 attenders)
DTI, London	(7th November; 28 attenders)

Structure of the Workshop

Prior to each workshop, every participant received the Delphi questionnaire and some summary information on the work of the Panel. Each workshop commenced with an introduction summarising the background of the UK Technology Foresight Programme and the key elements of the work of the Panel to date. This was typically followed by presentations by guest speakers who had been invited to comment on the future in their sector of industry. Participants then formed syndicate groups (of around 8-12 people) and discussed the Delphi questionnaire (in general terms - not for specific topics) and the key elements of a successful manufacturing economy in 20 years, then presented the main points from their sessions to plenary. Finally, a review was carried out, focusing on the priorities for manufacturing and the advantages and disadvantages of the UK as a manufacturing centre.

Technology Foresight Programme and Delphi Questionnaire

There was some criticism about the complexity of several of the Delphi topics and also about the format of the questionnaire. It was felt that the format was biased towards technical topics and not business process topics. In discussing the Foresight process, the consensus was for a balanced input from market pull/ technology push and also a recognition of the importance of allowing 'radical' ideas to come forward. The idea of scenario development was widely supported. Foresight needs to be a process which 'creates' (not predicts) the future and which is an ongoing, dynamic model with full government support. In general the consultation process in the workshops was viewed as more valuable than the Delphi questionnaire.

Education & Training

There was a uniform view throughout the workshops that all elements of education and training were key to the future of manufacturing industry in the UK but there was debate over the balance of skills to be obtained during education and during post-employment training.

At primary and secondary school level the need is for quality teaching in science and engineering by specialists who would encourage the best students to move into appropriate technical degrees. The importance of quality teaching was also key to raising basic numeracy and literacy levels of early school leavers.

At university level there was a feeling that specialist skills were generally well taught but that degree training should include a range of non-technical skills including project management, interpersonal skills, problem solving and business awareness in order to produce well-rounded graduates. It was felt academic teaching needed an industrial context and that communication and crossover between academe and industry must increase.

Continuous professional development should be used to give people skills in management as well as technical subjects and to allow retraining/updating of specialist skills. Life time learning (at all levels) needs to be better targeted at the individual/company and preferably take place in the workplace.

Teamwork was repeatedly cited as being an area under emphasised in UK education yet which had key implications to industry in terms of the crossfunctional teams and networks increasingly prevalent today.

The need to identify the core competencies needed in 20 years and put them into the education system now was clearly identified. Education (particularly at school) also has a major role to play in improving the image of UK manufacturing industry and thus the desirability of being part of it.

Research and Development

There was a clear view that R&D is key to the future of the UK and that there needs to be both strong industry- based research work (in companies and universities) and also longer term speculative R&D in universities in order to promote both incremental development and step changes.

Research in academe needs to be directed towards business processes as well as manufacturing processes. There was a general view in the majority of industry sectors that there could be as much benefit from better business processes as from technological developments. Research into best practice/competitor analysis and dissemination/application of this into/by UK companies could be focused in centres of excellence in the UK

UK must ensure there is always some 'blue sky' research (level varies by discipline) being carried out which has no apparent economic value to ensure we stay at the forefront of radical innovation. Generic (or underpinning) research is also a key element but should not be confused with blue sky.

There was strong support for a database of all UK (or even global) R&D projects to be held centrally and incorporate a search/access service to allow SMEs in particular to utilise the database even if they did not have suitable IT links.

The Enterprise of 2010

There was a clear view that the distinction between manufacturing and services will continue to break down over the next 20 years with the key element being the ready access to skills not their in-house availability.

Company structure will shift from the integrated enterprise (multi-functional teams in a company) to the extended enterprise (managing teams across a supply chain) to the virtual company (core competencies across a network of companies). Key competencies for this future are team building and team working.

The integrated supply chain was widely regarded as fundamental to the enterprise of the future and requires excellent, rapid communications (using IT) and stable business relationships to allow effective, concurrent supply chain management. Design integration will also be expanded into suppliers as more and more subcontracting of non-core activities occurs. The enterprise of the future must have a clear knowledge of its core competence needs.

The customer relationship will grow in importance as the expectations for variety and customised products increase. The skills of the design process must include effective involvement of the customer. Companies must take advantage of the best IT tools integrated with the best of human designers.

Concurrent engineering is important in providing both speed to market for new products and also in ensuring that the technical features of the product are integrated with those of the process. Rapid prototyping is coming into use now but the concept of on-screen design direct to production was not considered practical (nor desirable - market testing, trials) in 20 years.

The increased customisation will mean shorter product life cycles and will produce a move towards smaller, more flexible units for production (even multinationals are breaking into discrete units) with distributed manufacturing for components but assembly closer to customers. This will require new, small scale, reconfigurable processing/manufacturing plants and supporting new technologies.

Although individual sectors all described specific process technology needs there was universal agreement that the two fundamental background elements were viewing design, manufacture, supply, etc. as a single, integrated process and requiring a clear understanding of the manufacturing processes being used.

People and Organisation

Engaging the support of all the workforce (including providing an overview of business objectives and creating a set of shared management/worker values) is a basic requirement of the future 'lean' companies. There was already a view being expressed that people are the biggest competitive advantage a company has and that success can be achieved by recruiting the right people and adding the right skills.

Management skills (including training in visitor/scenario planning) need to be improved to allow successful implementation of changes. Management must take the lead by demonstrating and communicating understanding of the business, commitment to integration, flexibility and a willingness to learn (from shop floor and competition).

The rewards structure needs to be changed to place more emphasis on teamworking.

The social responsibility of employers was interpreted in widely differing ways but overall it was felt that there needed to be a balance of people and technology (eg automation) and a flexibility in the approach to the changing role of the workplace (ranging from community workplace providing crèche,

school, OAP facilities to the remote controlled or even 'dark' factory).

Finance and Entrepreneurship

It was broadly agreed that demands for rapid returns on investment led to a risk aversion culture in the UK. It was felt that this severely inhibited development and expansion involving capital outlay, particularly in medium sized companies devoid of government start up money. The risk avoidance culture needs to shift to a risk management culture and the financial disincentive to carrying out R&D and investment in new fields needs to be removed.

Combined with this is the need to promote the influence of technologists at board room level. Inward investment into the UK (either in terms of money or facilities) was seen as important to future UK prospects.

Regulation

Legislation was seen as expanding rapidly and the importance of being aware of future legislation (in terms of time to react to changes) was a major driver. This was seen as a particular problem for SMEs; and trade associations and government have a key role here as providers of information on new rules.

The emphasis of legislation was clearly seen as shifting to Brussels and the need for UK companies/government to go into Europe and influence/reduce the regulation process was well supported.

Regulation is seen most often as a constraint but can equally be viewed as a driver of innovation and hence an opportunity.

All legislation must be made much simpler and clearer and be enforced with common sense so as not to impose undue disadvantage on UK operators.

Information Technology

There must be a move away from 'off the shelf' IT packages towards more user friendly, specific and relevant use of IT in particular companies.

The growing volume of information (from customers, suppliers, shop floor) and need for more communication will lead to greater need for IT, but simplified business processes can reduce this to a manageable level. This is a key point, in that IT must be aligned to efficient business processes or it merely adds to the confusion.

IT/communication will be particularly relevant in SMEs to allow them to remain competitive but implementing this may require practical support (either from the MNEs they support/service or government).

The availability of IT and all the associated tools and services (eg virtual reality, data mining, structured databases) will have a clear impact on management structures and practices. The development and application of new IT tools must be simultaneous in order to ensure they are meeting business needs.

Other Issues

Environment (and associated legislation) was critical for some sectors (eg chemicals) but was generally viewed as non-critical.

IPR was again viewed as key in some sectors (eg design intensive areas such as pharmaceuticals) but not in others, where speed of change outpaced the patenting processes. The cost of supporting patents was also becoming prohibitive.

Sensors and control systems were repeatedly highlighted as an underpinning technology which was key to understanding/improving manufacturing processes. Materials processing and the need to move it from an art (skill based) to a science (knowledge based) was also focused on for the same reasons.

The role of SMEs in manufacturing was discussed against most topics raised at the workshops. Their incorporation into the Foresight process was seen as essential and it was felt that their future would depend on focusing on core competencies and networking with each other, with academe and with MNEs.

Regional clustering of industries was discussed and it was agreed that once started a 'virtuous circle' of increasing company involvement and improving skills/ education occurred in the area but that the historical basis for starting a cluster was often a cheap labour pool based on destruction of an old industry. Incoming multinationals often bring their own cluster of world class suppliers to an area. Regional networking was taking place most strongly in Scotland, N Ireland and the North East where there were groups consciously attempting to create clusters of industries and competencies.

UK Competitive Position

Key advantages and disadvantages of the UK as a manufacturing base (either for UK companies or for inward investment) were identified at the workshop.

UK Advantages:

Political/social stability	Successful process industries
Some world class academics	Systems integration skills
English language	British Telecom
Entry point to EU	Natural resources (water, oil, gas)
Low cost base compared to Europe	Inventiveness/innovation
Availability of flexible workforce	Good transport links to the world
Improvisation	

UK Disadvantages

Short-termism (both financial & Research)	Lack of breadth of education
Poor image of manufacturing in society	Lack of industrial strategy
Lack of understanding in government	Disappearance of work ethic
Historic neglect of development	Risk aversion
Preoccupation with English language	Lack of machine tool industries

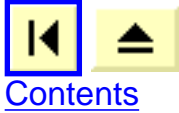
Lack of commercial exploitation skills/td> Lack of multi-skilling
Rigidity of labour compared to US Education not team oriented

Overall the workshop participants were all agreed on the need for the UK to maintain (and grow) its manufacturing base and to have a cohesive and consistent strategy for manufacturing in which the Foresight Programme could play a key role.

This Report was compiled by Dr. D. Winter.



Progress Through Partnership: 9 Manufacturing, Production and Business Processes



ANNEX 5 LIST OF KEY REQUIREMENTS DISCUSSED BY PANEL (FROM DELPHI AND REGIONAL MEETINGS)

The subsequent Tables provide a listing of the priority topics collated by the panel from the Regional workshops, from the responses to the Delphi questionnaires and from the panel's own deliberations.

The key requirements for success are listed against a number of Topic Areas which broadly correspond to the sub-headings within sections 4.1.1 (Business Processes), 4.1.2 (Technology) and 4.1.3 (National Infrastructure).

Table 5.1 - Priority Recommendations - List of key requirements for success (From Delphi and Regional Meetings)

Enabler	Topic Area	Requirement or Issue	Comment
Business Process (1)	Sales & Marketing Process	Market Information networks	Enables rapid response to opportunities or threats
		Identification of new product opportunities	And create new markets
		Business alliances	strategic or contract-specific For market access or technology sharing
		Strategic use of STEEP info.	To assess future trends and needs
		Product personalisation via IT & C network	Improves service to customer
	Product Introduction Process	Advertising	Improves knowledge of customer requirements Via new media networks etc. - precise targeting
		Home shopping	Changes logistics and supply networks
		Teamwork & Concurrent engineering	Optimise use of skills and processes Reduce development timescale and risk
		Methods to promote creativity	Learn from best practice
		Rapid prototyping	Graphical or solid model

	Project management	Reduce time and risk Plan, coordinate and control the development
	Product and Process simulation	Match the product and the process
	Automated material selection	Optimise performance, cost, risk and timescale
	Reliable CAD	Minimise risk of design errors Ensure product safety Ensure regulation & standards compliance
	Modelling, simulation & visualisation	Product and process
	Network of experts	Sub-contract work to specialists
	Alliances	Share development and supply with partners
	On-line expert assistance	Rapid technical assistance
	Ergonomics & aesthetics	Improve product performance and appeal
	Design for manufacture	Part of concurrent engineering
	Design for life-cycle	
	Product data management	Integrated database used throughout the enterprise
	Regulation	Which regulations apply? Prove compliance
	Standards	EU-International
Manufacturing Operations	Teamwork & Multi-skills	Total commitment and understanding of objectives Rapid and co-ordinated response to change
	Concurrent engineering	Rapid and risk-free entry into production
	Computer-based training	In the workplace
	Process repeatability and control	Key requirement
	Process simulation	Optimise and train before production commences Refine model with experience base
	24 hour plant	Increase utilisation (sector specific)

	Real-time efficiency measures	Rapid response to problems
		Minimise waste and rework
	Integrated supply chain	JIT throughout the supply chain
	Predictive process control software	Schedule material and process requirements
	Real-time automated reporting	Identify problems quickly and locally
	Training at production equipment	Effective training and use of operator time
	Integration of production & business controls	Customer, product and profit focus
	Effective IT integrated with business processes	Maximise benefits from IT
	Novel processes	Lower capital cost or running cost
	Capacity planning and scheduling tools	Optimise resource use
	Health and safety	With processes and products
	Logistics & Supply Processes	Alliance & networks Responsive and integrated
	Predictive production control	Optimise flows throughout the supply chain
	'Virtual enterprise'	Share the work to balance load or meet a special need
	Simulation of supply-chains	Avoid bottlenecks
	Effective IT	EDI and related rapid communications
	Transportation and distribution	Integrated and rapid
		High speed unmanned transport
	Material control process	Supply chain management
Benchmarking	Internal process mapping and analysis	Complete understanding of your enterprise
	Market & industry information networks	Determine the key competitive criteria
		Prioritise and quantify internal changes
	Cross-sectoral benchmarking	Learn from other industries

Table 5.2 - Priority Recommendations - List of key requirements for success (From Delphi and Regional Meetings)

Enabler	Topic Area	Requirement or Issue	Comment
Business Processes (2)	Training & Education	Team-building and multi-skills training	Constant training for all in the enterprise
		Methods to promote creativity	Determine methods with enhance innovation Manage in ways which encourage creativity
		Computer-based training	At workplace but networked to best sources
		Leadership training	Key management skills
		Project management training	A growth priority
		Communication skills	Effective communications
		Skill capture to Knowledge Based System (KBS)	Automating the knowledge base
		Continuous professional development	In association with higher education
		Post training evaluation	Feedback to training process
		Education into supply chain	Extend best practices beyond the enterprise
	Organisation, Management and Support Process	Company strategy	Generation and regeneration
		Geographic location of markets & operations	Increasing mobility
		Strategic alliances	For scale and scope
		Extended services to customers	eg local customisation
		Teamwork & multi-skills	Organise to meet needs of effective business processes
	Concurrent engineering	Communicate objectives and engage all Consider total life-cycle of product	
	Process simulation & Experience Base	Constantly improve and refine processes Test on model before implementing	
	Strategic use of STEEP information	Identify drivers of change and consequences Plan and implement best strategy	
	Computer based enterprise model	Optimise and integrate all business processes	

Technology Management (as a business process)	Business simulation techniques	Model and select competitive strategies
	'Virtual enterprise'	Share project with expert partners where necessary
	Effective IT	Use IT in support of good business processes
	Quality and continuous improvement	Throughout enterprise
	Risk management	as a formal discipline
	Financial management	Internal and external to company
	Security	Physical and IPR
	Core competence	Determine 'critical' and enabling technologies'
	Technology Benchmarking	Competitive analysis
	Requirement analysis	Future needs (Product and process)
	R & D strategy and sources	Source selection and management
	Intellectual Property Rights IPR	Ownership issues
	Licensing	External sources
	Joint ventures	External sources
Links with universities	External sources	
Links with contract research organisations	External sources	

Table 5.3 - Priority Recommendations - List of key requirements for success (From Delphi and Regional Meetings)

Enabler	Topic Area	Requirement or Issue	Comment
Technology	Process Plant Development	Automation & integration	Application specific
		Plant modelling and simulation	Optimise before construction
		Rapid and flexible plant (and 'Agile')	For rapid changes of requirements
		Reliable, repeatable, and maintainable plant	Minimise non-productive time
		Modular and reconfigurable	Extend use over wide product range
		Remote location and remote control	eg Ocean, space, underground
		Mobile plant	To meet temporary needs

	Efficient over wide throughout variation	The 'elastic factory'
	Reduced number of process steps	Cost and time reduction
	Sources of equipment and tooling	Proximity for service and development
	Low cost plant and processes	Key driver of change
	Automated test	Rapid, accurate and non-invasive
	Environmental impact	Minimise pollution, & blend with surroundings
	Health and safety	In and around the plant
	Security	Controlled access
	Plant for new technologies eg Bio or Nanoscale	Opportunity for new equipment
Sensors & Control	Self-compensating processes	Optimise for equipment or material variability
	Predictive production control	Link to supply chain
	Plant with automated maintenance	Condition monitoring & no unplanned maint.
	Process control integrated with business systems	Optimise for customer & profit requirements
	Automated assembly	Design for automation
	Automated test	Improve speed and accuracy
	Vision & optical sensors	Remote control
	Non-invasive sensors	Improve throughout
	Sensors to replicate customer perception	Check smell, touch, taste etc in factory
	'Fuzzy', 'Neural' and 'Holonic controls'	Continuing theme of improvements
Materials & Materials Processing	Rapid processes	Often needs process flexibility
	Application specific material	Design or specify with confidence
	Low-cost material process	Low energy, waste, and constituents
	Close dimensional tolerance	Reduce machining or finishing operations
	Reuse of material	Reuse, recovery or disposal
	Surface treatment	Long life/low friction at low cost
	Miniaturisation processes	eg Micromachining
	Modelling to predict and minimise energy	Optimise before building plant

	'Intelligent' materials	eg For sensors - 'mechatronics'
	Sterolithography	Need to extend range of materials
	Low-cost material tagging	Inventory control and for security
	Use of high temperature superconductors	In product and in process
Waste and Energy reduction	Modelling and simulation	Optimise during product & plant design
	New material processes	eg near-net shape processes
	Product recycling or disposal	Determine during design process
	Pollution	Including noise, light, electromagnetic
Modelling, Simulation & Visualisation	Process simulation & KBS	Continuous improvement of model
	Reliable CAD	Optimise before building plant
	Computer-based enterprise model	With known bounds of operation
	Business simulation	Identifies risks or potential problems
	Personalised product design - interactive	Optimise business processes
	Modelling to predict & minimise energy use	To simulate competitive activities
	Simulation of logistic and supply chains	Better choice for customers
	Modelling to predict & minimise waste	Improve knowledge of customers
	Computer-based training	Product, process & facility
Information Technology	Integrated supply chain	For time and cost optimisation
	Effective IT	Product, process & facility
	Real-time efficiency measures	In the workplace
	Markets information networks	Link through many supply levels
		Linked to optimised business processes
		Fast response to problems
		Rapid recognition of opportunities & threats

Networks of experts	Rapid assistance
Teleworking	Own employees and external experts
Data-mining	Refining knowledge base
Computerised based training	Throughout enterprise

Table 5.4 - Priority Recommendations - List of key requirements for success (From Delphi and Regional Meetings)

Enabler	Topic Area	Requirement or Issue	Comment
National Infrastructure	Education	Improved image and knowledge of manufacturing	
		Education at primary and secondary levels	Needs more understanding of industry Increase teacher training on industry
		Introduce FORESIGHT thinking	Methods which promote debates on future
		Industrial context for academic teaching	Show industrial applications
		Add to specialist degree courses:	Develop interpersonal skills Improve business awareness Improve business process awareness Improve problem solving skills
	Science and Technology Base	Project management training	In association with business
		Strengthen links with industry	Grow 'LINK' and other schemes
		More multi-discipline projects	A key manufacturing technology need
		Link with business processes	Show S & T in business context Emphasise wealth creation and QoL objectives
		Understand best-practice and competitive work	Industry and Academe must benchmark

	Maintain basic research content	Must undertake well ahead of exploitation Avoid 'short-termism' in universities
	Reward academics who work with industry	Present systems often penalises Affects individuals and departments Change research assessment criteria
Communications and Networking	Regional clusters of enterprises	Industries and academic partners where necessary Via 'Business Links' for example
	Low-cost high bandwidth communications	Need 'superhighway' etc Avoid disincentives to networking in/from UK
	Network of experts	Industry/industry and industry/academe
	Supply-chain networks	Totally integrated
	International networks	for alliances, markets, supplies and assistance
	Government links and networks	eg Export assistance, regulation assistance
	Trade association links	sectoral focus
	Professional bodies	To help improve practices
	Schools and education networks	Interactive networks - with industry links
	Electronic libraries	Rapid access
	Language training and translation	To assist exporters
Regulation	Need to simplify and reduce	Extend 'Deregulation Initiative'
	Increasing international pressure for legislation	UK must influence EU pressures
	Can be a driver of innovation	UK often too slow to take advantage
	Often seen as a threat	Most manufacturers see cost burden
	Environmental legislation increasing rapidly	Need to assist industry - particularly SMEs

Finance (government influence)

Shareholding structure in UK - 'short termism'

Disincentives for UK based firms

Risk aversion

Pressure for near term profits

Need for increased R & D

UK below most competitors

Increasing international mobility of finance

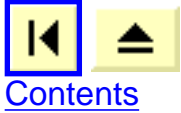
Can help business start-ups

Can risk short-termism & loss of UK IPR

Need for help on incentives from government



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ANNEX 6 REPORT OF THE MEETING ON 21ST OCTOBER 1994 AT THE POLICY STUDIES INSTITUTE

Introduction

The purpose of the meeting was to examine how potential technological and innovative developments fit into a broader picture of the evolution of the manufacturing sector in the national and international economy. The aim was to focus on some of the main expected trends and developments relevant to the future of manufacturing industry including economic, social, environmental and political factors.

Competitiveness

Competitiveness can be defined as relative performance at firm, sector and national level. Key measures of competitiveness include export market shares and the net trade balance. The key question is 'what are the determinants of competitiveness?' An answer to this question requires an analysis of both the economic determinants of competitiveness and of the associated social and political institutions and issues.

The current competitiveness of UK manufacturing has both positive and negative aspects. During the 1980s there was high productivity growth, and by the end of the 1980s there was an improvement in export performance. However, import penetration increased during the 1980s with a negative net trade balance in manufacturing occurring for the first time in 1983 and persisting since then. It is unclear as to whether the UK economy is now entering a sustainable period of export-led growth, or whether it will hit the classic constraints of skill and capacity shortages and return to consumption-led growth. At the same time, the UK continues to lag behind its main competitors in terms of its overall levels of productivity which are in the region of 25-40% behind some of its key competitor countries.

In discussing competitiveness, it is important to ask what the purpose of increasing competitiveness is and what sort of competitiveness is being sought. Does increasing competitiveness automatically lead to rising income, growth and employment? There is increasing concern over 'jobless growth' as a likely prospect for the future. It would also be possible for the UK to become highly competitive relative to the other EU economies by paying substantially lower wages than those other economies. However, the view was expressed that this sort of competitiveness was neither desirable nor feasible: the UK would not be able to compete in terms of low labour costs with some of the developing and newly industrialising economies. The UK should be aiming to move to a high value-added manufacturing sector which can then support a large service sector. There are important questions of how this transition to a much larger services sector is to be achieved. It will be necessary to develop a manufacturing sector of sufficiently high value-added that most people can be employed in services.

Achieving such a high value-added manufacturing sector and increasing the competitiveness of UK industry is in part a question of maintaining and increasing key skills, including managerial ability, but

these were not the only components. In some areas, such as software, developing countries are in a position to compete on skills. As well as key competencies such as design, innovation, management, and quality achievement, it is also extremely important that appropriate supporting infrastructures exist at both local and national level. One key difficulty in trying to develop these competencies is that firms are facing severe short-term price pressures and price competition at present. However, if firms respond only to those pressures, this makes little contribution to longer-term stability and value-added of the manufacturing sector. Competitiveness depends in part on flexibility, the ability to manage and introduce change, and the ability to find different ways of making, marketing, and managing the production process relative to competitors. Innovation can be one important factor in competitiveness, but fast diffusion and the increasing amount of collaboration between firms in R&D, means that innovation is not always the only, or the key, element of competitive advantage. At the same time, for many firms and even sectors, imitation and adoption of new technology may be as important as innovation. The distinction between the two is, anyway, not always precise as imitation may often lead to further improvement or innovation.

Manufacturing, Services and Employment

While the discussion recognised that there is an important issue of the relative transfer of employment from manufacturing to services, the view was also expressed that it is unclear, in many cases, where manufacturing ends and services begin. The division between the two appears to be increasingly blurred. This, in part, reflects organisational structure changes as well as technological changes. Many firms are subcontracting services that would previously have been carried out in-house and therefore counted as manufacturing activities. Nevertheless, while there is this blurring of the line between manufacturing and services, and while an efficient and diverse services sector is important as a contribution to the manufacturing sector, manufacturing is still important in its own right, in particular due to its major contribution to the trade balance.

The nature of the development of the services sector will be important not only in terms of its contribution to the performance and creation of a high value-added manufacturing sector, but also as the major sector in the economy and therefore the major provider of employment in the economy. The service sector is highly diverse in this regard as many jobs are highly skilled and well-paid, whereas other jobs are unskilled and low-paid. The key economic policy challenge is to ensure that both sufficient numbers of jobs are available in the service sector and that the unskilled are not employed at poverty wage levels. This is a question in part of activity levels, but is also a question of skill levels and training. There appears to be relatively little scope for increasing unskilled employment within the manufacturing sector unless there were an increase in protectionism.

Internationalisation

Internationalisation is one of the key factors influencing trends in, and the development of, the economy and firms. The increase in internationalisation is reflected in increased trade levels and in increased numbers of multinational enterprises investing in a wider range of countries. It is also driven in part by transport and telecommunication developments. The existence of multinational enterprises (MNEs) has made the relationship between the competitiveness of firms and the competitiveness of a country more complex. A firm is concerned with its international or global strategy and its global performance, whereas, with respect to the national economy, we are concerned with activity and performance levels within a certain area. It is not only MNEs that have a global reach - SMEs are also exporting substantial amounts and are entering into international alliances and collaborations as well.

The question was discussed as to whether national economies in any important sense can be said to

still exist. One view was that it may be more useful to focus on regional and supra-national systems, rather than the national economy. Economic and technological boundaries went across national boundaries and are different from social and political ones. An alternative view was that national economies are still important, both in terms of key macro constraints such as the trade balance, and also in terms of institutional and policy structures.

One important issue in an increasingly internationalised world is the extent of mobility of firms. One view, reflected in the work notably of Robert Reich, is that mobility, in terms of capital, information and technology, is so great that the only national characteristics specific to a national economy are labour and infrastructure. This extreme view of mobility was in general not accepted. Technology and knowledge are not instantaneously available and applicable, nor are all firms perfectly mobile. Some firms and sectors are more mobile than others, with standard commodity producers in a position to move around and look for the lowest cost location.

The discussion considered whether the increase in internationalisation was simply a continuation of past trends, or whether it was substantially different and opening up major new challenges. There were different opinions on this. One view was that internationalisation is essentially a continuation of previous trends. It is driven by MNEs and by technological developments together with government agendas with respect to trade and international agreements. Liberalisation of the utilities in telecommunications and infrastructure was thought to be one potential, important influence for further opening up internationalisation in the future. Another view was that the processes driving internationalisation have now accumulated to such an extent that it is creating a new set of circumstances even though no one process is particularly different in kind from what has happened in the past. The scale was qualitatively different.

A third view was that internationalisation is now qualitatively different. This was particularly due to the fact that there are now global markets in finance, although production has been internationalised rather than globalised. The globalisation of capital markets makes it hard for governments to use traditional levers of macro policy and, at the same time, they compel an extremely large amount of financial deregulation by national governments - in the absence of coordinated regulatory policy across countries. One result is that commodity producers can find it extremely easy to relocate profits to where they can get the highest returns. One example of this is that Japanese companies in the UK actually pay very little tax as much of the financial value-added can be repatriated. This also means that relocation of production gets financially easier. National governments would need to develop integrated corporate taxation if they were to capture some of this value. In terms of internationalisation of production, MNEs have to have a presence in the three big bloc markets. Quality producers in particular need to be mobile. In terms of where the firms choose to locate there are vicious and virtuous circles in operation. Thus, for example, IT 'super-highways' will cluster in growth areas and not in disadvantaged areas. At the same time, environmental factors may come to shape the process increasingly as consumers demand regulation and control with respect to issues such as the quality of food, air pollution, and transport quality.

The question of the role of inward investment in the UK was also raised. One view was that inward investment can raise employment if MNEs see the UK as an attractive low-cost location (as was the recent example of Samsung). However, the question was whether the UK as a whole actually benefits from inward investment, or whether the benefits are siphoned off. Even where an inward investor is producing apparently high-tech products this does not necessarily mean that it is adding value within the UK economy, it may be essentially an assembly operation. Multinational inward investment can act to drive down wages and skills. However, overall, it can be shown that MNEs tend to pay relatively high wages - this may not be the case, however, with respect to more recent inward investment. In terms of

the advantages and disadvantages in inward investment with respect to employment creation, there are, of course, two-way flows of investment in and out of the UK. The UK net figure for 1993 was only just positive.

Networks and Clusters

It was generally agreed that networks between firms - users, suppliers and competitors - were an important phenomenon to understand in the analysis of competitiveness, internationalisation and the role of government. Networks are not always geographically located but in many cases there are important local and regional clusters of related activities. Thus the presence of a range of firms has important externality effects which no one firm on its own is in a position to create or influence.

Such clusters perform more than one economic function through the provision of a series of benefits to the firms who are part of the cluster. These benefits include stimulation of: user-supplier communication; communication between firms at the same point in the production chain; local infrastructure expenditure; the local skills base, and overall levels of activity in the region. There are potentially, therefore, a series of cumulative/positive effects that may result from such clusters. The opposite side to this is that during a recession, or due to structural change, such clusters may disappear, and they cannot automatically be recreated by the decision of any one individual firm. This may indicate some role for government assistance.

The effect of MNEs on clusters is unclear. It will depend in part on their sourcing decisions. Thus, on the one hand, inward investment might stimulate clusters and local supplier networks and, on the other hand, if MNEs are sourcing from elsewhere, it may act to destroy and disrupt local clusters. Even where local suppliers do link to the multinationals, they remain very vulnerable to multinational decisions to source elsewhere.

Clusters may also arise for specific historical reasons and then there will be a positive/cumulative dynamic. This means that while there may not be substantial differences between areas or countries, those where clusters have developed for whatever reasons, may gain cumulative benefit while other regions will suffer cumulative decline. Local, regional and national infrastructure can be important influences on the formation of clustering.

The Role of Government

There was wide agreement that government did have a significant role to play with respect to the processes discussed above. The view was expressed that, in the UK as a whole, there needed to be an agreed agenda, or vision, for the development of UK manufacturing in particular, and for the economy as a whole. This needed to be a shared vision between government, business, and the labour force. It was argued that successful economies tend to have a shared political agenda with respect to the economy but that the UK does not. There have been mechanisms to try to consider such an agenda in the past - notably NEDO - but one of the key problems was a major failure to communicate the agenda to the outside world. There are also considerable differences in trying to communicate an agenda to large firms, to small firms, and to the wider community. The shared vision needed to go from the level of the SME, all the way up to the level of the nation as a whole. This would help with creating factors such as better training and skills for leadership and for the management of change.

While government clearly has a role in stimulating training and skills, this is not necessarily sufficient as

a role for government. In particular, there is substantial scope for government to develop policies with respect to networking and clusters to try both to facilitate and stimulate their development and to take action, if appropriate and feasible, where networks are being disrupted. This might be a question of government providing appropriate infrastructure. It might also be a question of government discussing with large multinationals their network structures in order to try to stimulate both clusters of innovation, and jobs and skill development. In this view, it would be mistaken to think there are fixed national advantages and disadvantages that determine what multinationals do and where they locate. One example of such policies was the new Belfast-Dublin corridor where there will be an attempt to stimulate the development of SMEs' networks to develop this area. One key aspect of this corridor is that it tries to work with the decisions of multinationals as it will give them access to the Single European Market and the existence of clusters of small firms may also provide an attractive location. MNEs on their own will not necessarily make optimal decisions with respect to sourcing and local supply and activity developments, but they may be guided that way by strategic policies without intervening inappropriately in business decisions.

Conclusions

Technology and innovation may constitute one part of successful performance, but it is clear they are only one aspect of a broader set of competitive factors. As internationalisation gathers pace, the key competitive factors may change but the ability to manage and influence change will remain central. Competitiveness is not just a question of individual firms, but of the level of overall economic activity and the quality of that activity within a country.

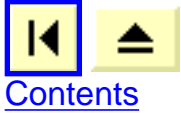
Competitiveness depends on the overall economic and institutional environment, on the nature of inter-firm relationships, and on the nature of firm-government relationships. It also depends on wider economic, social and political choices with respect to the environment, social provision and employment. Individual firms do not operate in a vacuum, but in the context of networks of firms, in the context of infrastructure, and in the context of institutions and regulations. Local and national government has a role to play in considering and influencing the nature of these networks and inter-relationships.

In this context, science and technology policy needs to be part of a wider and coordinated policy framework aimed at promoting both competitiveness and activity levels. The nature of industrial structures and the nature of future competitiveness will determine the relevance and nature of science and technology policy as much as the other way round.

This annex was contributed by Dr. K. Hughes - Policy Studies Institute



Progress Through Partnership: 9 Manufacturing, Production and Business Processes



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