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Irish Council for Science,
Technology and Innovation

Technology Foresight Ireland

Report of the Materials and Manufacturing Processes Panel

Forfás

Established by the Government and Forfás to advise on Science, Technology and Innovation

Executive Summary

This report summarises the findings of the Materials and Manufacturing Processes Panel of the Technology Foresight study. It takes a perspective to the year 2015.

During the Technology Foresight excercise the Panel considered the drivers for this sector and as a result two strategic questions were formulated. These focused the work of the Panel in developing long term strategies up to the year 2015, to address the issues these strategic questions raised.

1. *In what way will customisation and information technology affect the structure of manufacturing processes and systems in Ireland in 2015?*

and

2. *How will sustainable development in 2015 influence materials and manufacturing processes in Ireland?*

Although both strategic questions related to materials and manufacturing processes, the first question was oriented towards manufacturing processes and the second question towards materials. Four strategies were developed, two for each strategic question ((A) and (B) for question 1, (C) and (D) for question 2) and are as follows:

A. Concentrate on product strategies with a high value density and a high design and, therefore, a high value-added component.

B. Develop virtual manufacturing in its widest possible sense by building extended enterprises.

C. Introduce green manufacturing processes while keeping manufacturing competitive internationally.

D. Concentrate on strategic intelligence encompassing marketing and technology trends for materials.

These strategies address the following key issues as they relate to the year 2015:

- What will the future structure of the materials and manufacturing processes sector be?
- What type of companies will exist?
- What type of product(s) will they manufacture?
- Who will they employ to manufacture that product?
- What steps need to be taken to ensure the future competitiveness and success of this sector?

Key sectoral recommendations

Shift to High Value-Added

Companies which manufacture in Ireland should develop a high value-added capability (which would include R&D and new distribution mechanisms, for example) in materials-based products and services coupled with the ability to use virtual manufacturing. Additionally, green manufacturing knowledge and processes should be introduced where appropriate.

Technologies

World class centres of excellence in product design, materials applications and related engineering competencies are needed. These could be virtual centres of excellence. Programmes in Advanced Technologies (PATs) should be refined and developed in strategic areas such as materials and advanced manufacturing technologies. These technologies encompass design, robotics, sensing, modularisation, integration, modelling, new product introduction, reverse logistics, life cycle analysis and automated assembly on the manufacturing processes side and on the materials side encompass high precision machining, modelling of processing, modelling of materials, materials from renewable resources and the capability to adapt and use developments in bio-materials, polymers, composites, metals and ceramics.

R&D

- It is vital for the sector that the spend on industrial R&D increases. In many application oriented business areas, achieving a critical mass is within the scope of companies in Ireland
- It is important that the linkages and structures between third level institutions and industry are improved
- A multidisciplinary approach to R&D needs to be adopted and promoted
- The developmental cycle should be primed for customer orientated development projects in materials and manufacturing; structures should be put in place to encourage companies to facilitate this process
- Additional tax incentives are needed to raise fiscal support for R&D to the levels applied in our peer countries.

Education

- A multidisciplinary approach should be supported by the core engineering sciences
- The skills of team building, communication, innovation and creativity should be instilled in students throughout the entire educational system from primary through secondary and up to tertiary level.

Key cross-sectoral recommendations

- There is a need for a 'wired' country - an information society - so as to facilitate the use and adoption of current and emerging Information and Communications Technologies (ICT)
- Supply chain management expertise needs to be developed, particularly in the area of logistics for industrials products
- A recurring theme is the necessity to foster a culture and a climate to encourage creativity and innovation
- There is recognition of the fact that the business oriented skills of technical students need to be improved and of equal importance is the need to improve the technical skills of business students
- Investment in our educational system is necessary to improve technological awareness and computer literacy
- A culture where continuous professional development and life long learning are strongly encouraged in all companies, large and small, needs to be promoted.

Key Actions

Manufacturing companies and their suppliers

- To change their culture, invest in information communications technologies and move towards products and services that add value
- To access technical information as well as market information through linkages to the third level sector, technology use and skilled personnel
- To create a new mindset, review and simplify the development process, simplify the quality assurance process, develop project management and portfolio management skills and develop 'soft skills'
- To ensure that their long term 'green' manufacturing strategy is appropriate for their sector of the industry
- To develop a relationship with centres of excellence in R&D (including information and communications technology) in the third level sector, PATs and relevant research institutes.

Programmes in Advanced Technology (PATs)

- To become the recognised interface between industry and the third level sector for materials and advanced manufacturing technologies
- To ensure that the relevant PATs are strengthened and focused to respond to the recommendations of Technology Foresight and identify areas outside of existing expertise which need to be developed.

Third level sector

- To invest in product design courses. To incorporate marketing and market sensitivity components into technical courses
- Additional courses in 'green' industrial design, environmental science/engineering and production engineering to be offered
- Research, technology and innovation content to become mandatory for MBA courses as well as other business courses
- To establish the capability to undertake multidisciplinary R&D activities where appropriate. Ensure that teamwork, effective communications and where appropriate multidisciplinary experience is gained during graduate courses
- To ensure that third level students develop advanced information and communications technology skills
- To establish an exchange programme (i.e. those in education work in industry for a period of one to three years, as part of their 'in service training' and those in industry teach on a part time basis in their area of expertise).

IDA Ireland

- To attract product design companies to set up in Ireland and thereby increase the expertise available in the field.

Enterprise Ireland and IDA Ireland

- To use effective R&D and innovation strategies as a major measure of success justifying further support. Resources to be made available to ensure that this is the case. Ensure co-ordination between both bodies on this issue.

Enterprise Ireland and the Environmental Protection Agency (EPA)

- To advise on legislative requirements in relation to environmental issues. Incentives and assistance to be given to companies with a strategy to build on 'green' products and services. Ensure co-ordination with IDA Ireland on this issue.

Department of Enterprise, Trade & Employment

- To encourage, support and promote R&D linkages between third level and industry
- To focus funding on areas of technological excellence and avoid duplication of R&D effort.

Department of Education and Science

- To promote creativity and innovation through the educational system in addition to promoting science and technology

- To ensure that teamwork and effective communications skills are encouraged at all levels of primary and secondary education.

1. Current Situation

1.1 Introduction

This chapter gives a 'snapshot' view of the Panel's international and national perspective of the materials and manufacturing processes sector. The scope of the Panel's remit is as follows:

Materials development, selection and their conversion into value-added goods by the most effective manufacturing processes represent a key area. Here functionality, quality, reliability and productivity must be addressed. The technologies and skills involved span a wide area and impact many industrial sectors.

Included: Virtual enterprises, new manufacturing processes and materials, micro and nano-fabrication. Design and simulation, quality and reliability. This Panel would also consider wider organisation issues: interface between demand and production.

Excluded: Activities from factory back door to customer that had been considered by the Transport/Logistics Panel.

In 1997 there were 234,000 permanent employees in the manufacturing sector[1], approximately evenly split between Irish-owned and foreign-owned companies. Manufacturing exports were IR£28.1 billion in 1997. The Irish economy expenditures of manufacturing industry in 1996 was IR£19.2 billion[2]. Wages and salaries amounted to IR£4.2 billion and IR£9.5 billion was spent on Irish raw materials. The figures quoted here are the most recent available and relate to manufacturing industry as defined by Forfás. This does not necessarily correspond to the manufacturing and materials sector defined above but does indicate the vital importance of the manufacturing sector to the economic well being of Ireland.

The remit of the Panel is very broad and by its very definition is not confined to one particular industry. This has the advantage of taking a broad view of materials and manufacturing processes as they impact across a range of sectors from engineering to electronics through to the medical device and healthcare sectors. On the other hand, it is not a straightforward task to summarise where Ireland is positioned. The approach taken is to indicate the trends which are felt to be prevalent at the moment.

1.2 Materials

The International Perspective

State of Development of Materials Technology

Materials are the building blocks which underpin many technologies and therefore impact on virtually every industrial sector. The list of materials, which also includes their processing, comprises of abrasives, adhesives, bio-materials, ceramics, composites, glasses, metals, polymers, rubbers and semiconductors.

The development of new materials and therefore of new processes leads to the growth of new industries.

[1] *1997 Employment Survey, Forfás*
[2] *1996 Annual Survey of Irish Economy Expenditure, Forfás*

Key Applications

In any given sector, one final integrated product, e.g. automobile, hip joint, personal computer, mobile phone, power turbine, catalytic converter, etc. is made up of various different materials processed in different ways. This leads to a complex system of supply chain inter-relationships, and of manufacturers under pressure to lower costs and produce high reliability, high quality components for the end product. In future, the customer will increasingly specify a set of properties which must be matched by the material.

The international trends are the development of new/improved materials, with increasing emphasis on functionality and the interaction/interface between materials. New and improved processes are being developed in order to improve design (modelling of material properties), performance (weight, wear, joinability, smartness etc.) and size reduction (miniaturisation, ultra precision manufacture). Increased competition as well as legislation (e.g. EU directives, restrictions on the use of certain materials) are driving cost reduction (process improvement, near net shape production), packaging, recyclability and environmental friendliness. Issues of increasing importance will be bio-friendliness, recycling, reprocessing, waste reduction and disposal.

The National Perspective

The trends outlined in the international context will impact on all industries. For example, impact is expected to be greatest in the electronics and communications sectors, particularly in the short term; these sectors are fast becoming sub-sectors of the automotive, aerospace, other transportation, energy and construction/ infrastructure sectors where ‘smart’ components/devices are needed. A further example is that of polymers which play a key role in sectors as diverse as electronics, medicine, pharmaceuticals and food processing.

The trend towards using modelling processes is pronounced i.e. rapid results are sought which genuinely reflect what is going on in real world processes. Improvements in design practices and technologies are necessary to maintain and increase competitiveness. The process engineering and food engineering sectors, as a whole, will have to take on board new technologies and move towards an engineering science approach (process simulation, finite element modelling, rapid prototyping etc.) in order to survive and grow.

As economic growth continues, more emphasis on quality of life issues will impact on the healthcare and recycling industries.

Only very few companies in Ireland have the capacity to undertake significant R&D. There is, currently, limited competency in the field of materials but the potential is very great.

1.3 Advanced Manufacturing Technologies (AMT)

The International Perspective

State of Development of Advanced Manufacturing Technologies (AMT)

The critical issues are cost, quality and cycle time (time-to-market and delivery). This situation requires dramatically improved work practices and advanced technologies. Combined with the globalisation of manufacturing there is a trend to outsource so that companies can focus on core competencies while still striving to maintain ‘agility’. This is reflected in the recognition

of the importance of the 'Human Element' which enables companies to be flexible and innovative. Consequently, issues such as recruitment, motivation, learning and training have come to the fore.

There are a number of specific advanced manufacturing technologies which are important: manufacturing process development; the impact of information communications technology on manufacturing; the design, development and performance of machine tool and automation systems; evaluation models; practices for improving the product development process; production control and logistics systems; training techniques.

Key Applications

The electronics, automotive, aerospace and healthcare industries are the ones in which the greatest competition exists and which are at the forefront of the development of the newer techniques. There is increasing pressure on other industries to become more cost competitive and improve efficiency. These techniques are now being introduced in more traditional industries such as food and consumer goods as well as in smaller enterprises such as design houses and the software industry.

The National Perspective

Traditionally, AMT techniques have been implemented by assembly type manufacturers. Ireland has strengths in some of these technologies but these are mainly in the multinational companies. However, there has been increasing pressure on sub-suppliers to these companies to incorporate AMT technologies. It is, therefore, important that the core competencies of manufacturing companies in Ireland are developed and those of multinational companies 'embedded' in order to prevent the easy or swift transfer of operations outside of Ireland. Issues to be addressed include the importation of technology (processes, products and R&D) and components.

Most companies are aware of the benefits of ISO 9000, the ISO 14000 family of standards and, to a certain extent, of the impact of World Class Manufacturing (WCM) techniques. The further concepts of Business Excellence and the European Foundation for Quality Management (EFQM) are new to Ireland. In 1997 the Irish Quality Association changed its name to Excellence Ireland to make the development more obvious. The issue of quality, European standards such as the CE mark, are important for manufacturing companies particularly those involved in the export market. The issue of design for 'de-manufacture' is of increasing importance as a result of European directives and legislation.

2. Driving Forces

2.1 Introduction

After considering the current state of the defined materials and manufacturing processes sector from a technology standpoint, the Panel looked towards the future to identify the trends which could impact on the sector. The Panel decided to look at the materials and manufacturing processes sector from two different perspectives. Although these two perspectives are complementary, there are different factors impinging upon them as we look towards the year 2015.

2.2 Materials, Product Design and Manufacturing

Looking to a future 15 to 20 years hence, it is envisaged that there will be a world where new materials will play an important part. This will mean continuous changes to materials processing techniques which encompass new techniques for existing materials as well as for new materials. This creates an opportunity to build upon the existing expertise within Ireland to exploit these developments. Recycling, re-usability, extended life and zero-waste processes play a major role, where manufacturing processes are likely to be strongly influenced by environmental considerations, both market driven and legislation driven, and the materials to be used have not yet been fully developed. Ireland's position vis-à-vis advanced materials should be addressed as should the strengths and competencies that Ireland should have in order to position itself for this environment.

In summary, innovative product design and its implementation in production processes are felt to be the main drivers for materials. Sustainable development and time-to-market are important issues associated with these drivers. In this context sustainable development is defined as development which meets the needs of the present without compromising the ability of future generations to meet their needs.

2.3 Fabrication Processes and Systems

In 15 to 20 years, it is envisaged that there will be a world where many innovative and competitive products will have to be manufactured to individual specifications. There will be a need to interpret these requirements so that valuable products can be delivered with customised features. Manufacturers will have to be able to decipher and translate these specifications (interactive design and simulation). The batch size could be one. Information and Communications Technologies (ICT) will enable the customer to monitor at what stage the product is in the design and manufacturing process and track its delivery. Ireland's place in this value chain needs to be addressed in terms of the type of manufacturing company that will be based in Ireland and the segment of the market that they will target or operate in and the type of manufacturing activity that will be undertaken.

In summary, product attractiveness, quality, customisation, competitiveness and the demand for e-commerce are felt to be the main drivers for fabrication processes and systems. E-commerce in this context is defined so as to include the technologies to both manufacture and sell products by using ICT.

2.3 Addressing the Future

In following the Technology Foresight process, consideration of the drivers for the materials and manufacturing processes sector led to the formulation of two strategic questions which focused the work of the Panel on the long term strategies which were required to best position Ireland for the year 2015.

First Strategic Question

In what way will customisation and information technology affect the structure of manufacturing processes and systems in Ireland in 2015?

Second Strategic Question

How will sustainable development in 2015 influence materials and manufacturing processes in Ireland?

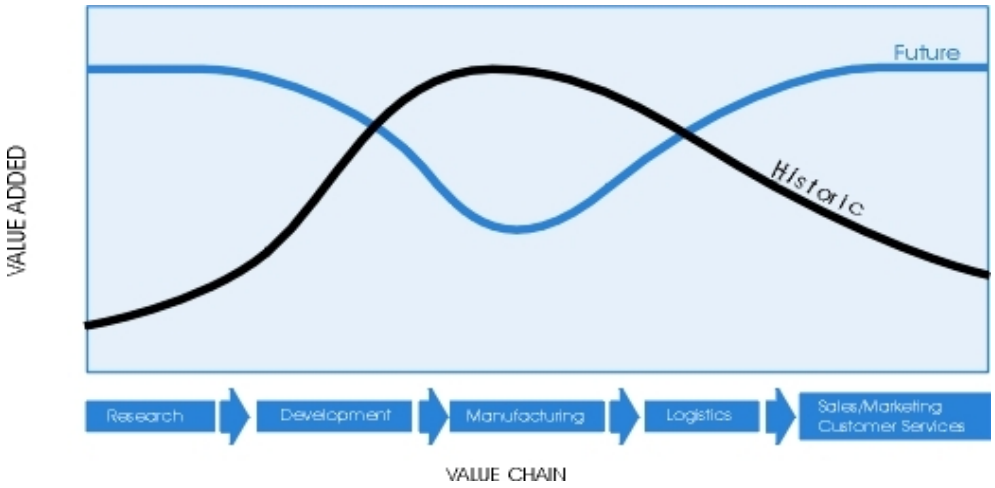
Both questions relate to materials and manufacturing processes, with the emphasis on manufacturing in the first question and the emphasis on materials in the second question.

3. Strategies

3.1 Introduction

As Ireland approaches the new millennium the pace of technological change is accelerating. There is an increasing need to address the issues raised by globalisation. Opportunities will arise for the companies which can act with increased efficiency and increased responsiveness. New and improved materials will require new methods of process design and manufacture. There is also a recognition that the structure of manufacturing industry is changing, Figure 1.

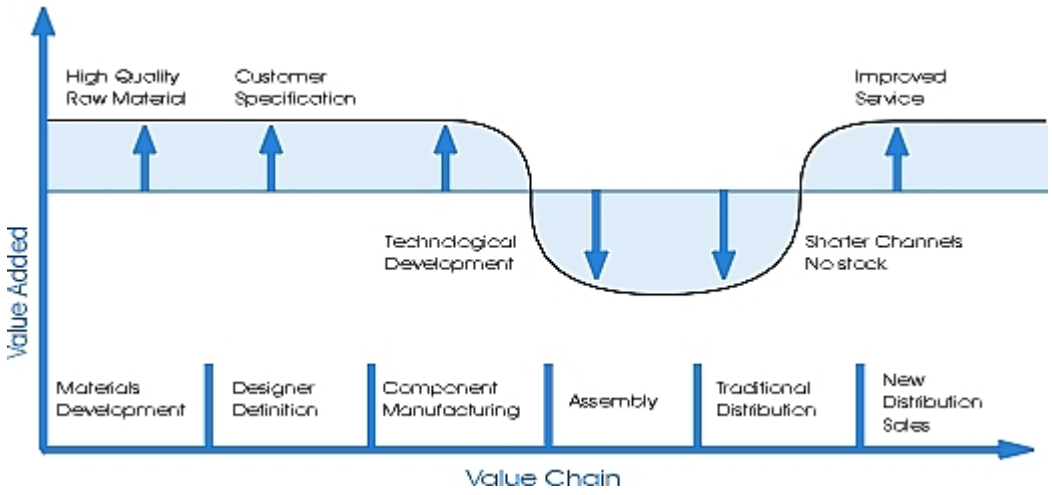
Figure 1. The Changing Structure of Manufacturing Industry



The value-added component in products is being pushed back along the chain i.e. to design and materials/components production and forward to new distribution techniques, customisation and services as illustrated in Figure 2.

The challenge is to put long term strategies in place which address the issues which this raises, such as: the type of manufacturing company which will exist in Ireland; the type of product that it will manufacture and the type of individual that it will employ.

Figure 2. Changes in the Value Chain[3]



The strategies detailed below are listed in order of importance as they pertain to the strategic questions, with strategies A and B addressing the issues raised by the first strategic question, and strategies C and D addressing the issues raised by the second strategic question.

3.2 Strategies for the First Strategic Question

Two strategies, A and B, were devised to address the issues raised by the first strategic question.

'In what way will customisation and information technology affect the structure of manufacturing processes and systems in Ireland in 2015?'

Strategy A is

Concentrate on product strategies with a high value density and a high design and, therefore, a high value-added component.

Who is the strategy for?

This is a strategy for businesses which aspire to be outside the commodity area. This is for exporting manufacturing companies as well as companies that produce high value, low physical volume and low density products, for example, software, semiconductors, control systems products such as sensors and transducers, healthcare and medical products.

Implicit in this strategy is the recognition that Ireland is an island which is isolated geographically from our trading partners. The future success of the companies that manufacture in Ireland will depend on strategies that recognise these facts and address them in the context of a global market. Being geographically isolated from export markets necessitates that our exported products (products also include services such as design expertise and software programmes) should not only be of high added value but be capable of efficient and economic transportation.

What technologies are needed to implement this strategy?

The focus of this strategy is on the importance of 'added benefits' through innovation. To facilitate this, design and technology must be exploited.

Fundamental science and engineering training are core disciplines. However, there is a need to break down traditional divisions between disciplines. It is at the boundaries and overlapping interfaces of disciplines that innovation is most likely to occur and where real needs can be addressed at this time. The areas of mechatronics, robotics, and machine vision which involve synergy between mechanical engineering, computing and electronics are prime examples.

There is also the need for integration technologies such as miniaturisation which require skills in materials science encompassing polymers, ceramics, alloys and bio-materials technologies. Automation technologies leading to greater flexibility and manufacturing agility are required. To take advantage of greater 'agility', product innovation skills and advanced industrial design skills, technologies and tools are also needed. Developments in toolmaking may be an important enabling technology. An important area which should not be neglected is the development of technologies associated with packaging both to protect the product itself and to sell the product. Automated assembly methods will be needed for quality and cost effectiveness.

What are the technical R&D requirements?

Market and technical intelligence are needed in order to ascertain that the right development direction is being taken and that customer specifications are addressed. This strategy requires targeted research in areas driven by industry demands and funded by industry. This approach would be facilitated by the development of centres of excellence in materials and process technologies in order to promote, make accessible to industry and take advantage of the expertise available in third level institutions. It is vital to improve the linkages between third level institutions and industry.

Research is needed on integration technologies to link the electronic, mechanical, material and other aspects of a product.

Applications are required for micro-products, transducers and sensors.

This strategy also requires the development of suitable software for improved design methodologies.

What are the enabling research and development requirements?

- Enterprise driven research and development into project management and supply chain management are needed
- Precision and ultra-precision manufacturing technologies are also required.

What are the educational requirements?

There is a need for courses in product development, design and project management skills. Design (virtual, tools, systems) and process evaluation, materials science, marketing and innovation management courses are also needed. The educational requirements are for a core understanding of engineering sciences; additionally, there should be more emphasis on innovation and customer sensitivity in technical subjects.

What are the investment requirements?

- Public-private partnerships should be encouraged
- It is important that there is recognition of the knock-on multiplier effect of investment in R&D. Significant state support is needed at the company level to bring Irish R&D up to international standards. State aid to companies should refocus to place more emphasis on R&D in order to allow the creation of new products; it will also help to embed multinational companies
- Product design courses which integrate customisation, lean manufacturing and logistics are needed
- Equipment and facilities in educational institutes for teaching should be better funded and their use encouraged
- Infrastructural investment is also required to develop a transportation corridor to Europe.

Are there other components to this strategy?

A further component of this strategy is the development of a national transport optimisation strategy - Ireland to Europe. To fully exploit this strategy will require the development of appropriate supply chain management expertise.

What steps should be taken to implement this strategy?

- Attract product design companies to Ireland
- Build on the existing expertise in the educational infrastructure
- Incorporate marketing and market sensitivity components into existing technical courses
- Improve the linkages between third level institutions and industry
- Support entrepreneurship and industrial R&D (with emphasis on the D). Raising the tax incentives to the levels experienced in our peer countries would facilitate this. For example there is tax relief at 35% in the UK as opposed to 10% in Ireland. To stimulate R&D in Ireland, tax relief at a rate of at least twice the company R&D spend would make up for the perceived tax penalty in Ireland due to its relatively low tax environment.

Strategy B is

Develop virtual manufacturing in its widest possible sense by building extended enterprises.

Who is the strategy for?

This is a strategy for many, and potentially all, manufacturing and service companies.

Implicit in this strategy is the recognition that companies will have to adapt and embrace advances in information and communications technologies (ICT) to enable short term relationships, national and international, where specialist companies, third level institutions or other outsource providers come together for a limited time to exploit a particular niche market. Long term stable partnerships with leading companies in the value chain which will also need to be considered. Advances in ICT will also enable companies to respond to increasing customisation by allowing interaction between the manufacturer and the product user.

What competencies are needed to implement this strategy?

Computer and communications literacy throughout the entire workforce.

What technologies are needed to implement this strategy?

Networking will be central, so ICT will play a key role in this strategy. The areas which would be at the forefront are telecommunications, electronic data interchange, internet technologies and e-commerce. The other areas of importance are:

- Technologies associated with robotics and sensing
- Modularisation - so as to enable the customisation of products
- Product design technologies - to enable virtual manufacturing such as computer aided engineering for product and process design
- Modelling for logistics design and virtual production modelling.

What are the technical research and development requirements?

For companies capable of entering into long term supply relationships where significant customer value is added, it is essential that they have an R&D advantage (a developmental capability) or develop a relationship with an R&D provider such as a research institute, programme in advanced technology (PAT) or third level college. In tandem with e-commerce applications, new business software is needed to enable extended enterprises to operate - this area is very much at the developmental stage. Rapid product development technologies and IT to allow sharing of the outputs for prototyping, pilot manufacture etc. are vital to this strategy.

What are the enabling research and development requirements?

In order to facilitate virtual manufacturing, the management of Intellectual Property Rights (IPR) needs to be addressed with services designed particularly for small companies (<50 people) working together on short duration projects.

The need to have a flexible platform within a company will mean new IT and organisational developments are required as will the ability to mimic informal organisation communications to handle unstructured data internally and externally.

There is also a need for access to on-line technical databases.

What are the educational requirements?

Technology 'know-how' courses are required which break down the traditional division between disciplines and which would include innovation and financial training. This recognises that there is a tension between the goals of professional bodies which grant accreditation and the course time demanded at third level institutions. Professional bodies need to recognise that there cannot be any successful co-operation without successful communication. Related to this is the issue of 'cross-pollination' between technical and non-technical courses. For example, there are legal, economic and financial components to many engineering courses but there are no technical components to economic, financial or legal courses.

The appropriate software and IT skills will also have to be developed. A key area will be the training of truly flexible manufacturing technologists with refinement and development where necessary. There is also a need to develop the communication and interpersonal skills of technical staff.

In order to promote virtual international manufacturing, the weakness in languages, which occurs at secondary level, will have to be addressed. It is also anticipated that applied social sciences to facilitate coping with complexity and change are needed.

What are the investment requirements?

There are investments required throughout the entire educational sector, from primary through to secondary and third level, to address the topics raised above. In some areas it will require additional funding by the Government. Manufacturing companies will also have to invest in in-house training and recognise the need to address life long learning. Manufacturing companies will also have to invest to ensure flexibility in their manufacturing systems as well as investing in compatible IT systems.

There is also a specific requirement for investment in service companies, research centres and programmes in advanced technologies which would facilitate reliability testing, prototyping and automation. These technologies and services are not widely available and are an expensive expertise for one company to have.

An infrastructural investment would also need to be made to support transport and logistics as well as an appropriate IT structure. This strategy could be undertaken with a positive bias towards regionalisation, with the West and North West areas gaining priority.

Are there other components to this strategy?

- An important component is for companies to take a global perspective
- There is a possible requirement for intermediary facilitation agents who would organise networks
- New approaches to industrial relations might be needed to allow this strategy to work to best effect.

What steps should be taken to implement this strategy?

Publicise what can be achieved in smaller companies through linkages, case studies, the lessons learnt, and the adapting of those lessons. A vital component is to improve the linkages between industry and third level institutions in order to promote and use the R&D facilities that are in place through the development of the required research centres and programmes in advanced technologies (PATs).

Additionally, there should be better education on technology and innovation management for both management and students, for example technical components could become a mandatory part of MBA courses.

Industrial relations conditions in future partnerships should address old rigidities while stressing recognition of industrial worth and respecting individual contributions.

3.3 Strategies for the Second Strategic Question

Two strategies, C and D, were devised to address the issues raised by the second strategic question.

'How will sustainable development in 2015 influence materials and manufacturing processes in Ireland?'

Strategy C is

Introduce green manufacturing processes while keeping manufacturing competitive internationally.

Who is the strategy for?

This is a strategy for all manufacturing companies.

Implicit in this strategy is the recognition that sustainable development is an increasingly influential factor both for legislative and consumer demand reasons. Green manufacturing is not simply something that can be done at a week's notice. It has implications for how products are designed, what they are made of, how they are made and how they are disposed of. There is a recognised tension between 'greening' manufacturing processes and maintaining competitiveness internationally . A balance needs to be struck as to when these processes are introduced. If delayed until mandatory, there is a danger that companies will be left behind more forward planning competitors. If these processes are introduced too early, the company may be burdened with extra associated costs.

The emphasis and level of impact of this strategy will vary from industry to industry i.e. there are three levels in this strategy: compliance with legislation; being good corporate citizens; and the potential of a competitive edge.

What technologies are needed to implement this strategy?

The technologies needed will address new ways of manufacturing existing products as well as new products. This will entail the evaluation of new materials technologies, new processing technologies, new production technologies, recycling and separation, re-usability, energy conversion, environmental technologies and packaging technologies (including materials use and design). Reverse logistics to enable recycling of used products and the data management systems that accompany that technology would also be valuable components.

What are the technical R&D requirements?

Design for recycle as well as for re-manufacture is a developmental requirement. This strategy requires access to materials data bases and information into alternative materials processes. Allied to this is the need to develop centres of excellence in selected areas of separation technologies. There will be a need for R&D to develop new systems and tools to support recycling. A different approach to design, for example design for de-manufacture and re-manufacture, will be needed in conjunction with developments in reverse logistics. An important area will be the development of suitable packaging technologies.

What are the educational requirements?

An important requirement will be education regarding environmental and legislative drivers. There is a need to build in a ‘green’ component and awareness to our education system, from primary to MBA. Specifically, there will be a need for courses on industrial design, environmental science/engineering and production engineering in this regard.

What are the investment requirements?

Investment to encourage innovation and R&D. A gradual investment by companies is probably required as a phased switch to ‘green’ manufacturing is the most likely occurrence. There is investment needed in suitable course development by the educational institutions and by the Government. There is also a need for centres of excellence. These centres need not be centralised and could be virtual.

Are there other components to this strategy?

Legislation will drive this strategy but clear EU legislation that does not place companies at a competitive disadvantage with respect to world wide markets is required. Companies also need ready access to the information which will allow them to assess their options.

What steps should be taken to implement this strategy?

Deliver on the requirements of the elements listed above. Incentives or assistance should be made available for going ‘green’ e.g. developing green components. A role could exist for the EPA (Environmental Protection Agency) and/or Enterprise Ireland to provide experts/consultants who would advise on compliance, appropriate technologies etc.

Strategy D is

Concentrate on strategic intelligence encompassing marketing and technology trends for materials.

Who is the strategy for?

This strategy is aimed at companies and service providers who wish to exploit the opportunity of new materials, particularly high technology companies. It is also a strategy for agencies with responsibility for foreign direct investment.

Implicit in this strategy is the recognition that Ireland is not, in general terms, a creator of the materials needed for manufacturing products in Ireland. However, as a nation our strength needs to be in adapting and using the developments in materials that will occur. Thus, there is a need to be aware and to keep abreast of technology trends while maintaining a high level of general materials science expertise. This will position companies to take advantage of and exploit these advances and have the capability to process and use these new materials. With access to good information systems, an innovation culture and bright people, developments are possible to grow Irish companies and embed multinationals through the promotion of R&D.

Ireland has an advantage over other countries in three respects: we are a small and non-threatening nation regarded as having a good educational system and being good communicators.

What technologies are needed to implement this strategy?

Materials science, industrial design and advanced manufacturing technologies are most important. Additionally, the technologies to allow technical information management. Personal contact with the front-line of technology and markets is also essential. Technologies to promote the use of specialist information gathering analysis - internet, databases, ICT etc. are essential particularly given the volume of information that exists. On a broader level the need for continuous action is vital through Technology Foresight, technology watch and evaluation studies.

What are the technical R&D requirements?

A key requirement is the availability of creative personnel with the appropriate interpretative technical and market skills. There is also the need for intelligent database systems. A related need, which will also be important, is the development of predictive social development forecasting techniques to help Irish companies identify product needs and opportunities.

What are the educational requirements?

There is a need for training on how to be ‘connected’ for small firms so as to take advantage of opportunities that will arise through the use of ICT. Marketing should be a component of existing technical courses. Ideally what is required is technically literate social scientists and socio-economically aware technologists. Ultimately, there is a need for a pool of materials scientists with the training and expertise to exploit developments in materials technologies.

What are the investment requirements?

Industry to undertake and invest in this strategy - regularly - and act on its findings. There is a wealth of information in colleges which can be accessed and existing structures can be built upon. If industry initiates and pays then it can demand the information that it requires in the format that it needs. Funding to support the necessary structures to allow collaboration would also be required. A related issue is the development of high quality technical databases with international collaborative back up.

Are there other components to this strategy?

It is important to promote R&D, particularly in small companies. To encourage R&D in these companies where there is no interface between industry and third level institutions is an important issue. A levy similar to the FÁS levy would ensure that these companies become proactive in looking for their 'pound of flesh' and thus get involved in the strategy. The third level institutions should be aware that the supply chain companies in the electronics, pharmaceutical and healthcare sectors have expressed a need for this type of service.

An important facet of this strategy is to inform government and industrial development decision making.

What steps should be taken to implement this strategy?

Co-ordination of support from Enterprise Ireland, IDA Ireland, Forfás and any other intelligence gathering agencies. 'One-stop-shops' should enable access to the relevant expertise available in the country on a given topic. The existing programmes in advanced technologies for materials and advanced manufacturing technologies and other relevant technology centres could play an important role in this respect.

4. Recommendations

4.1 Introduction

This chapter highlights the common themes and areas of importance that have been identified in the course of this study. The work of the Panel has primarily concentrated on the specific sector, as defined by its initial remit. It has always been recognised that to isolate the work of one Panel and hence one particular sector or aspect of a sector, from that of any other Panel is neither feasible nor desirable. Thus, the recommendations draw initially on specific sector issues and subsequently from broad cross-sectoral issues (which would impact on some or all other Foresight Panels).

Although the strategies in chapter 3 are presented in considerable detail, the key recommendations are indicated below. It should be noted that these form only part of the strategies which are detailed in this report and should be read in that context.

4.2 Sector Specific Recommendations - Materials and Manufacturing Processes Sector

- Manufacturing companies should develop a high value-added capability in materials-based products and related services coupled with the ability to use virtual manufacturing
- Raise Irish R&D activity to international standards; significant state support is needed for this. There should be a concerted effort to attract product design companies to Ireland, to boost existing expertise in this area
- The developmental cycle should be primed for customer orientated development projects in materials and manufacturing. Structures should be put in place to encourage companies facilitate this process. The ability to cope with multidisciplinary projects should be underpinned
- Further develop green manufacturing knowledge and processes where appropriate
- World class centres of excellence in design, materials applications and related engineering competencies should be developed. These need not be centralised and could also be virtual centres of excellence. By definition, these will be cost effective and used for the outsourcing of research by industry. The duplication of R&D effort should be avoided
- There is a need to develop a multidisciplinary approach to research and development based on the core engineering sciences. This must ensure that team building, communication, innovation and creativity are instilled in students throughout the entire educational system from primary through secondary and up to tertiary level.
- The programmes in advanced technologies (PATs) should be refined and developed in strategic areas, such as materials and advanced manufacturing technologies, to support the implementation of these recommendations. These technologies encompass design, robotics, sensing, modularisation, integration, modelling, new product introduction, reverse logistics, life cycle analysis and automated assembly on the manufacturing processes side and on the materials side high precision machining, modelling of processing, modelling of materials, materials from renewable resources and the capability to adapt and use developments in bio-materials, polymers, composites, metals and ceramics

4.3 Cross-Sectoral Recommendations - applicable to all sectors

- Prime, encourage and develop industrial research and development and related research, technology and innovation activities
- Structures and linkages between the higher education sector and industry should be improved so that the skills that exist in the former can be drawn into the innovation stream
- Aggressively promote and encourage innovation and creativity through training and the media
- Create a 'wired' country - an information society - so as to facilitate the use and adoption of current and emerging information and communications technologies
- Invest in the technological awareness and computer literacy of all students specifically but also of the general population
- Develop the technical skills of students who specialise in accountancy, business studies, economics and other similar courses and similarly develop the business oriented skills of scientists and engineers
- Promote a culture where continuous professional development and life long learning are strongly encouraged in all companies, large and small
- Develop the supply chain expertise which would include transportation and logistics
- Undertake a sustained approach to preparing for the future which should involve Technology Foresight, technology watch and evaluation studies.

5. Implementation and Follow up Actions

5.1 Introduction

This chapter sets out the key actions that are required by the stakeholders in order to build on the work of the Materials and Manufacturing Processes Panel. The key actions are divided into two sections, one set for the sector specific recommendations, and the second for the cross-sectoral recommendations. A time scale for their implementation is indicated where appropriate.

5.2 Sector Specific Key Actions

Manufacturing companies and their suppliers

- To change their culture, invest in information and communications technologies and move towards products and services that add value

  Time scale: < 5 years

- To access technical information and market information through linkages to the third level sector, technology use and skilled personnel. Create a new mindset, review and simplify the development process, simplify the quality assurance process, develop project management and portfolio management skills and develop 'soft skills'

  Time scale: Start immediately

- To ensure that their long term 'green' manufacturing strategy is appropriate for their sector of the industry

  Time scale: < 5 years

Programmes in Advanced Technology (PATs)

- To become the recognised interface between industry and the third level sector for materials and advanced manufacturing technologies

  Time scale: < 2 years

- To ensure that the relevant PATs are strengthened and focused to respond to the recommendations of Technology Foresight and identify areas outside existing expertise which need to be developed

  Time scale: < 1 year

Third level sector

- To invest in product design courses. To incorporate marketing and market sensitivity components into technical courses

  Time scale: < 3 years

- Additional courses in 'green' industrial design, environmental science/engineering and production engineering to be offered

  Time scale: < 3 years

IDA Ireland

- To attract product design companies to set up in Ireland and increase the expertise available in this field

  Time scale: < 5 years

Enterprise Ireland and EPA

- To advise on legislative requirements on environmental issues. Incentives and assistance to be given to companies with a strategy to build on 'green' products and services. Ensure co-ordination with IDA Ireland on this issue

  Time scale: < 3 years

5.3 Cross-Sectoral Key Actions

Manufacturing companies and their suppliers

- To develop a relationship with the centres of excellence in R&D, including information and communications technologies, and in the third level sector, with programmes in advanced technology (PATs) and relevant research institutes.

  Time scale: Continuous

Third level sector

- Research, technology and innovation content to become mandatory for MBA courses as well as other business courses

  Time scale: < 3 years

- To establish the capability to undertake multidisciplinary R&D activities where appropriate. Ensure that teamwork, effective communications and where appropriate multidisciplinary experience is gained during graduate courses

  Time scale: Continuous

- To ensure that third level students develop advanced information and communications technologies skills.

  Time scale: Continuous

- To establish an exchange programme (i.e. those in education work in industry for a period of one to three years, as part of their 'in service training' and those in industry teach on a part time basis in their area of expertise)

  Time scale: < 3 years

Enterprise Ireland and IDA Ireland

- To use effective R&D and innovation strategies as a major measure of success justifying further support. Resources to be made available to ensure that this is the case. Ensure co-ordination between both bodies on this issue

  Time scale: Start immediately

Department of Education and Science

- To promote creativity and innovation throughout the educational system in addition to promoting science and technology

  Time scale: Continuous

- To ensure that teamwork and effective communications skills are encouraged at all levels of primary and secondary education

  Time scale: Continuous

Department of Enterprise, Trade & Employment

- To introduce measures to further stimulate industrial R&D

  Time scale: < 2 years

- To focus funding on areas of technological excellence and avoid duplication of R&D effort

  Time scale: < 2 years

- To encourage, support and promote R&D linkages between third level and industry

  Time scale: Continuous

Department of Environment

- To ensure that the relevant EU legislation enacted is clear and does not put Irish industry at a competitive disadvantage

  Time scale: Continuous

- To ensure that the relevant information is available to Irish industry

  Time scale: Continuous

Forfás

- To undertake periodic measurements of entrepreneurship and innovation using the latest measurement techniques available

  Time scale: Continuous

- To undertake a sustained approach to preparing for the future which should involve Technology Foresight, technology watch and evaluation studies

  Time scale: < 2 years

Appendix I – Methodology

The methodology used to carry out the Foresight study was influenced by that used in the Netherlands and is outlined below. A time horizon to 2015 was taken.

A Panel (see Appendix II) representing stakeholders from industry, the public sector and higher education was convened and met several times. The Panel agreed on a definition of the sector which would be the remit of the Materials and Manufacturing Processes Panel. The Panel assessed the current situation and Ireland's position within that situation. The long term drivers for change in this sector were identified and strategies to address the issues raised by these drivers for change were developed.

An important part of the methodology involved the use of scenarios, which are hypothetical futures that Ireland could face, set in the year 2015. These were constructed by determining and evaluating the uncertainties which could impact on the driving forces identified by the Panel. The end result was a number of coherent pictures or scenarios of possible futures. The scenarios provided a tool for examining the effects and consequences of unpredictable events and developments that might impact on the long term strategies being considered. It is a method of 'future proofing' long term strategies.

A wide consultation process was also undertaken (see Appendices III and IV) to ensure that there was an opportunity for those stakeholders outside of the Panel to contribute to the excercise. A consultative workshop was organised to allow public debate and discussion of the strategies being developed by the Panel as well as to provide an opportunity for validating the direction that the Panel had been taking.

Appendix II - Panel Composition

Professor Jane Grimson, Chairperson	Dean of Engineering	Trinity College Dublin
Dr. David Melody, Deputy Chairman	Vice President, R&D	Loctite Ireland Ltd
Paul Blackie	Lecturer	Athlone Institute of Technology
Professor Werner Blau	ead, Department of Physics	Trinity College Dublin
Professor Gerry Byrne	Head, Department of Mechanical Engineering	NUI - Dublin
Dr. Eamonn Cahill	Consultant	Irish Productivity Centre
Niall Carroll	Managing Director	ACT Venture Capital Ltd
Garrett Dee	R&D Manager	Reagecon Ltd
Dr. Joseph Dowling	Technology Development Manager	Bausch & Lomb Ireland
Dermot Keena	Advanced Manufacturing Technologies Manager	Motorola BV
Dr. Ardawan Lalui	R&D Director	Vitalograph (Ireland) Ltd
Jim Lawler	Director	AMT Ireland
Professor Pat Mallon	Head, Department of Mechanical and Aeronautical Engineering	University of Limerick
Professor John Monaghan	Head, Department Mechanical and Manufacturing Engineering	Trinity College Dublin
Dr. Eamonn Murphy	Research Director AMT Ireland	University of Limerick
Paul O'Brien	Managing Director	Raychem International
Eoin O'Driscoll	Vice President, International Operations	Ascend Communications
Dr. Barry O'Connor	Lecturer	NUI - Cork
Brian O'Grady	Managing Director	BSM Ireland
Matt Russell	Head, Department of Manufacturing Engineering	Dublin Institute of Technology
Eamonn Sheehy	Business Development Manager - Healthcare	IDA Ireland
Dr. Joe Healy, Secretary	Technical Operations Manager	Materials Ireland

Appendix III – Submissions

The Panel took inputs from a number of expert contributors in the form of written submissions, interviews and a structured questionnaire. An international perspective was also obtained where suitable contributors were available. The names of those who contributed are listed alphabetically below.

Contributors within Ireland		
Dr. Jaqueline Allan	Policy & Planning Analyst	Forfás
Mr. Dietlief Becker	Consultant	Becker & Associates
Professor Jim Browne	Director of CIMRU	NUI - Galway
Ms. Mary Carroll	NPI Consultant	AMT Ireland
Mr. Sean Conlon	Managing Director	Excellence Ireland
Dr. Fiona Coyle	Research Officer	MI Polymer Development Centre
Ms. Jacinta Darmon	R&D Manager	Green Isle Foods Ltd
Mr. Malcolm Farmer	Consultant	
Mr. Tim Foran	Research Officer	MI Metals Processing Research Centre
Mr. Bob Flynn	Research Officer	Materials Ireland Research Centre
Dr. Michael Gilchrist	Lecturer	NUI - Dublin
Ms. Anne-Marie Gill	Site Manager for Management Development	Intel Ireland Ltd
Professor Tom Glynn	Head, Department of Physics	NUI - Galway
Mr. Clive Lee	Senior Lecturer	Royal College of Surgeons in Ireland
Ms. Caroline Lonergan	Managing Director	Novell Ireland Software
Mr. Frank Lynch	R&D Manager	Guinness Ireland Ltd
Professor Vincent Mc Briarty		Trinity College Dublin
Mr. Reg McCabe	Director	Plastics Industry Association
Mr. Sean McEntee	Managing Director	Laserform (Ireland) Ltd
Mr. John McGrory	Manager	Industrial Control Centre
Dr. Ita Mc Stravick	Research Officer	IDA Ireland
Mr. Ciaran Mulhall	Managing Director	Devtec Ltd

Mr. Pat Murphy	Manufacturing Manager	Howmedica International Inc
Mr. Brian Nangle	Chief Executive Director	Munekata Ireland Ltd
Mr. Paul Normoyle	Technical Staff Member	Trinity College Dublin
Dr. Cathal O'Domhnaill	Research Officer	MI Polymer Research Centre
Ms. Aoife O'Riordan	NPI Manager	Eurologic Systems Ltd
Mr. Nigel Roberts	Technical Manager	Boart Longyear Ltd
Dr. Paul Tompkins		Bioserve Ltd
Mr. Paddy Wally	Consultant	
Mr. Ray Walsh	Research Officer	MI Metals Processing Research Centre
Dr. James Whickam	Employment Research Centre	Trinity College Dublin
Mr. Rod Williams	Manufacturing Manager	Hewlett Packard Ltd

Consultation to give an International Perspective		
Dr. John Campbell	Chief Executive, Xenva Ltd	UK
Dr. John Carroll	Consultant	Canada
Mr. Phil Faulkner	Business Development Manager	UK
Dr. Norman Waterman	Chief Executive, Quo-Tec Ltd	UK
Professor David Williams	University of Loughborough	UK
Professor John Wood	Chair, UK Materials Foresight Committee	UK

Appendix III – Submissions

A one day consultative workshop was held on August 31st 1998, where 60 invited stakeholders discussed the issues raised by the panel.

Dr. Jaqueline Allan	Forfás
Ms. Sisse Anderson	Design Partners
Mr. Dietlief Becker	Becker and Associates
Dr. Eamonn Cahill	Irish Productivity Centre
Dr. Alun Carr	NUI - Dublin
Ms. Mary Carroll	AMT Ireland
Professor Joe Cogan	NUI - Dublin
Mr. Sean Conlon	Excellence Ireland
Dr. Fiona Coyle	MI Polymer Development Centre
Dr. Seamus Curran	Horcom Ltd
Dr. Finbar Dolan	CR Bard Ltd
Dr. Denis Dowling	Enterprise Ireland
Dr. Mark Elliot	Farran Technology Ltd
Mr. Malcom Farmer	Consultant
Mr. Bob Flynn	Materials Ireland Research Centre
Mr. Tim Foran	MI Metals Research Centre
Dr. Mike Gilchrist	NUI - Dublin
Professor Tom Glynn	NUI - Galway
Professor Stuart Hampshire	University of Limerick
Mr. Frank Lynch	Guinness Ireland Group
Mr. Reg McCabe	IBEC
Dr. Gerry McCarthy	Braun Ireland Ltd
Mr. Howard McConnell	International Coatings and Adhesives
Dr. Nick McDonald	Department of Psychology
Dr. Feargal McGeough	Wavin Ireland Ltd
Mr. Colin McGookin	Waterford Crystal
Dr. Fiona McSherry	MI Metals Research Centre
Dr. Ita McStravick	MI Coatings Research Centre
Mr. Pearse Moroney	Sola ADC Lenses Ltd
Mr. Ciaran Mulhall	Devtec Ltd

Mr. Colm Nolan	NEC
Mr. Tadg O'Brien	Microsemi Ltd
Dr. Cathal O'Domhnaill	MI Polymer Research Centre
Mr. Paul Redmond	Boston Scientific Ireland
Mr. Jim Ryall	Hi-Life Tools
Mr. Colm Shiels	Raychem International
Mr. Brian Stephens	Design Partners
Mr. Eanna Timoney	Adtec Teo
Dr. Paul Tompkins	Bioserve Ltd
Mr. Paddy Wally	Consultant
Mr. Ray Walsh	MI Metals Research Centre
Dr. James Wickham	Employment Research Centre
Dr. Killian Halpin	Forfás
Mr. Fergus Whealan	ICTU
Professor Werner Blau	Trinity College Dublin
Mr. Garrett Dee	Reagecon
Dr. Joe Dowling	Bausch & Lomb Ireland
Professor Jane Grimson	Trinity College Dublin
Dr. Ardawan Lalui	Vitalograph (Ireland) Ltd
Mr. Jim Lawler	AMT Ireland
Professor Pat Mallon	University of Limerick
Dr. David Melody	Loctite Ireland Ltd
Dr. John Monaghan	Trinity College Dublin
Dr. Eamonn Murphy	AMT Ireland
Mr. Paul O'Brien	Raychem International
Dr. Barry O'Connor	NUI - Cork
Mr. Eoin O'Driscoll	Ascend Communications
Mr. Brian O'Grady	BSM Ireland
Mr. Matt Russell	Dublin Institute of Technology
Mr. Eamonn Sheehy	IDA Ireland