SWOT Overview of Manufacturing Industry in Europe: 
Background to a European Strategy for IMS

Report prepared by:

The Institute for Prospective Technological Studies
European Commission Joint Research Centre
(James P. Gavigan & Hector Hernández)

in co-operation with:

The Irish Productivity Centre
(Eamonn A. Cahill)

&

Cranfield University School of Management - UK
(Prof. Colin New, Dr. Alan Harrison & Mr. Fred Lemke)

for:

The European Intelligent Manufacturing Systems Secretariat -
European Commission (DG XII.C & DG III.F) at the behest of
the European IMS Industrial Advisory Group

EUR 18103 EN
Foreword

In mid 1997, the European Industrial Advisory Group overseeing European participation in the IMS initiative (i.e. an international R&D collaborative scheme on Intelligent Manufacturing Systems), requested a synthetic overview of the competitive and technological Strengths and Weaknesses of manufacturing industry in Europe, as well as the emerging Opportunities and Threats it faces, with a view to working out a more focused European IMS strategy. This report has been produced by IPTS in response to that request.

Firstly, the S.W.O.T. overview component of this study, represents syntheses produced on the basis of available literature and two expert consultation workshops. Linked to and building on this, the report also scans and discusses several options for a European strategy vis-à-vis the participation of European firms in IMS. This discussion interprets ‘strategy’ mainly from the point of view of preferred thematic focus and preferred target participant typologies, although, at the end of the report, an attempt is made to position these two dimensions in a frame relative to other dimensions of the broader ‘strategy space’.

On the whole, it became apparent in doing this literature based survey, that the challenge of producing a coherent EU wide SWOT picture was fraught with several difficulties. Firstly, on the basis of the standard economic indicators and statistics, the overview picture which it was possible to draw up, remained at too aggregate a level to permit a straight-forward identification of clearly differentiated and justifiable options for a strategy. In the ‘technological’ domain, frustration was encountered at a lack of information available reflecting capabilities and prospects in the domain of ‘soft’ technologies, wherein lies the main thrust of the IMS overall technical frame.

On the positive side, the overview did point to two (at present, rather fragmented) bodies of literature which contain the type of information which was required for the purpose of the SWOT overview, including multi-country/ multi-sectorial benchmarking of plant practice and performance, and national technology foresight reports. Unfortunately, no coherent body of literature on any of these counts exists at EU level, but some very useful insights and information were extracted from what was available. An important message deriving from this is the need for action at some appropriate level to compensate for this large information gap.

The strategy options discussion, consists of the description of several themes each of which constitutes a basis for a set of focusing criteria. The arguments are developed in a way which is designed to be non-prescriptive, but still points to how some of the themes could be taken up and rendered much more specific by making certain number of limiting choices.

The results of the study were presented to a plenary meeting of the EIAG in Seville on 4th May 1998.

James P. Gavigan & Hector Hernández

Acknowledgment

The input of Felix Bellido - IPTS is acknowledged by the authors.
SWOT Overview of Manufacturing Industry in Europe: Background to a European Strategy for IMS

TABLE OF CONTENTS

Executive Summary 1

I. Introduction 6
   I.1 Background 6
   I.2 Interpretation of the specification 6
   I.3 Approach and Methodology 7

II. IMS framework 8

III. EU Policy Context 10

IV. Manufacturing Industry in Europe: Strengths, Weaknesses, Opportunities, Threats 12
   IV.1 General competitiveness perspective 12
   IV.2 Technology perspective 14
   IV.3 R&D, innovation & competitiveness (points from recent Second European S&T indicators report) 16

V. Discussion of Options for a European IMS Strategy 19
   V.1 General strategy considerations in the IMS context 19
   V.2 Strategy-setting approach and options 20
      V.2.1. An integrated strategy? 20
      V.2.2. Criteria-based strategy themes 21
         1. IMS and RTD Framework Programme 21
         2. Sectoral discrimination 21
         3. Growth Products 23
         4. Key technologies 23
         5. Key technology selection criteria 25
         6. Soft technologies 27
         7. International R&D co-operation #1 - general challenges 29
         8. International R&D co-operation #2 - some specific themes 31
         9. Technology innovation and diffusion, and the role of SMEs 32

VI. Conclusions 34

References 36

Annex I. European Industry ‘Competitiveness’ SWOT Overview by The Irish Productivity Centre. I-1

Annex II. Technology Profile of European Industry by Cranfield University. II-1

Annex III. Original proposal for the SWOT study; Terms of reference for the sub-contracts. III-1

Annex IV. Participants in the two study workshops held 21-22 Jan. and 19-20 March 1998. IV-1
EXECUTIVE SUMMARY

This report presents the results of a study carried out for the European Commission in relation to European participation in the Intelligent Manufacturing Systems (IMS) international R&D cooperation scheme. IMS is motivated by phenomena such as globalisation, the changing labour and market conditions, environmental issues and increasing cost and complexity of R&D in manufacturing.

The purpose of this work was to explore strategic options for optimising the IMS implementation in Europe. It was supported by two separate studies aimed at analysing the position of European manufacturing industry (mfg-E), in terms of competitiveness (results in Annex I) and technological capabilities and prospects (Annex II). The intermediate results of these studies were debated and further refined in two workshops (the terms of reference and workshop participants are given in Annex III and IV).

Given the vast breadth of the subject, it was out of the scope of this study to provide a detailed sectoral picture of mfg-E, as was the provision of an exhaustive description of technological needs that could potentially be addressed within the IMS programme. Instead, a generic view is taken, focusing on strategic aspects of manufacturing activity, keeping a broad perspective (to avoid a ‘picking winners’ approach), and on the other hand concentrating on issues that can be sensibly addressed at the IMS level.

The main part of the report is structured into descriptions of four dimensions suggested as a frame against which to formulate an IMS strategy, i.e. 1. the IMS framework and EU RTD policies, 2. the competitive position of mfg-E respect to its main competitors, 3. the technological capabilities residing in, or available to mfg-E and 4. the factors governing international cooperation and knowledge transfer. Furthermore, the report is completed by a description of different approaches and options for setting up such a European IMS strategy.

Outset conditions: IMS framework and EU policy objectives

The first set of conditions is defined by the current IMS framework and the EU policy context. Projects under IMS follow a “bottom-up” proposal approach and are guided by a number of principles, aiming to assure equitable and balanced co-operation, industrial relevance, inter-regional and geographically distributed consortia, to cover the full innovation cycle and fair IPR allocation and diffusion of results. The scope of projects is also bound to five specified technical themes, namely total product life cycle issues, process issues, strategy/planning/design tools, human/organisational/social issues and virtual/extended enterprise.

Regarding the policy context, implementing IMS as part of EU RTD programmes implies complying with the EU policy objectives and principles. In particular, the scope of IMS projects should be aligned with the shifting of the RTD framework programme towards achieving more focus, integration and critical mass. In addition, attention
should be paid to coordinate IMS with similar or complementary activities, e.g. other national or EU R&D programmes or standardisation activities, in order to avoid wasting efforts and to stimulate synergies across Europe.

**Competitiveness position of EU manufacturing industry**

This section (see details in Annex I) provides an overview of the performance of mfg-E, as a first approach to understanding the manufacturing technology needs that could be addressed within IMS. The analysis is mainly based on literature review of macroeconomic indicators, namely value-added, employment, productivity and export performance, elaborated for low, medium and high technology sectors. This is further complemented with a more focused analysis of demand issues such as capital goods, fast moving consumer goods, staple commodities and some other selected manufacturing themes. Finally, the conclusions are formulated in terms of an European SWOT analysis (strengths, weaknesses, opportunities and threats) from and respect to US and Japan.

Here, the overall situation in European manufacturing industry presents a mixed picture. In high-technology sectors, Europe has a range of potential opportunities but its performance to date in keeping abreast of the US and Japan has been weak. Europe has not entered the same level of strategic alliances with Japanese or US companies as the other two groups have with each other.

The technological base in Europe, founded on high quality basic research, remains strong but a shortfall in investment is preventing the gaps, particularly with Japan, being closed. However, not all of the difficulties faced by Europe can be resolved with additional investment in R&D. Much of the lack of strength in European manufacturing lies in the failure to adopt new techniques and technologies with an attention to detail at the implementation stage, which would involve ensuring that new principles and concepts are tailored to the precise conditions prevailing.

The main strengths of manufacturing industry in Europe are in medium-technology sectors rather than in high-technology sectors. Europe’s competitive capability would be improved by focusing on developing its position in the high-tech sectors as these are the growth areas. In particular, more SMEs need to be involved in the high-tech sectors to bring Europe in line with the US and Japan.

**Technology profile and knowledge infrastructure**

This part attempts to examine the technological capabilities available to European manufacturing and its future prospects in relation to the IMS activities (see details in Annex II). The aim is to complement the overview of mfg-E, in the previous section, with a forward-looking analysis based on the S&T situation and prospects. The analysis includes a review of national technology foresight exercises and recent S&T
indicators, and takes account of trends in production systems such as the extension of the value-chain and the decreasing ‘relative’ economic importance of the manufacturing sector per se. In this respect, the study places emphasis on distinguishing and characterising the ‘soft’ technological factors involved in manufacturing such as resources organisation, design and logistics, as opposed to the ‘hard’ factors more directly associated with actual equipment and artefacts.

The results of this section show a widely dispersed and partial picture of the technological capabilities and prospects for Europe. This is due, in part, to the obvious problem in attempting to bring together such a variety of studies, most of which present country-based rather than EU-based results, and also because ‘soft’ technologies have been under-researched and are still poorly understood. In spite of such limitations, the report includes a summary in terms of a SWOT analysis of the outlook of ‘key technologies’ in Europe.

Some of the salient points indicate:

• **Strengths.** Generally, a solid science base in Europe, with technical excellence in many domains, e.g. German textiles, UK electronics suppliers, etc.; and a wide range of universities and research organisations are being connected at EU, national and regional levels.

• **Weaknesses.** Relatively weak industrial application of key technologies (only 21% of European applications are rated as ‘strong’). Falling numbers of graduates in technical courses, fragmentation of university technology research, slow responsiveness by universities to rapidly-evolving technologies and poor articulation of industry research needs.

• **Opportunities.** Need to develop an effective R&D infrastructure. Stimulate strong links between research institutions and industry, focusing on industry clusters or cross-cutting technologies and providing explicit dissemination mechanisms.

• **Threats.** Insufficient long-range planning and coordination of technology policy, lack of flexibility and slowness to adapt new manufacturing practices.

*International cooperation and knowledge transfer mechanisms*

Important criteria indicating promising areas on which to focus IMS activities may also be derived from the analysis of factors governing international cooperation and technology transfer. This is particularly important from the public policy viewpoint, the double challenge of which is to keep in Europe a fair part of the potential benefit of the co-operation and to maximise the diffusion of results throughout the European knowledge network. Several reports found in the literature show that there exist a clear differentiation impact of international R&D cooperation according to the type of firm, sector of activity and specific characteristics of the technology. In fact, there seems to
be a higher interest to cooperate for firms or sectors dealing with the development and application of complex and science-based technologies (higher R&D expenditure), production of goods for the global market and network structures with many links to external organisations. On the contrary, there is less cooperation interest for technologies developed and applied within local specific production systems. These results generally agree with the objective of seeking higher complementarity between technology innovation and diffusion, e.g. targeting generic and interdisciplinary technologies. It is also in line with the EU priority of strengthening innovation policy and is especially important for the SME network.

Formulating an European strategy for IMS

The last part of the main report comprises a detailed discussion on the different possibilities to combine the information acquired, in order to indicate where are the most promising areas to invest in IMS projects.

General strategy considerations are provided, summarising the main driver factors and boundary conditions for European action in the IMS context. It is reminded the need to respond to emerging manufacturing challenges such as globalisation, accelerating product innovation and shifting of priorities in the production system. The latter refers to the increasing importance of up-stream components, e.g. to integrate the global supply chain, and down-stream elements, e.g. to include services and customer satisfaction. This aspect is particularly important because it implies a transfer of costs and jobs to new areas, and these new areas involve higher proportion of ‘soft’ technologies.

Significant strategy elements can be also derived from approaches used to focus national technology policies, in particular from foresight exercises which have developed sophisticated procedures and comprehensive criteria to select promising technologies, e.g. clustering them in terms of their ‘attractiveness’ and ‘feasibility’ from national standpoints. A straightforward approach would be to combine such national experiences with the EU policy objectives and experience in organising RTD programmes. However, some questions may be raised, due to the different characteristics and context where IMS takes place, in particular its bottom-up feature and the international competition challenge.

Finally, the summary and conclusions of the study are translated into a number of criteria-based strategy options and approaches. Although the options presented are not mutually exclusive nor prescriptive, they can be combined in different manners to delimit the working space for IMS. Some of the criteria can be straightforward derived from the framing conditions, e.g. the IMS and EU RTD objectives. Other criteria are deduced from the studies of the competitive and technological position of mfg-E, e.g. the need to cope with the most important European weaknesses, i.e. to strengthen the organisational capability and to improve the effectiveness of the innovation system. On
these aspects, the criteria discussed include a sectoral discrimination, products with
growth potential, favouring ‘soft’ technologies, bottleneck of technology diffusion and
role of SMEs. Also, as discussed above, the methodology and criteria employed for the
national foresight exercises provide important lessons that can be applied, at least
partially, in the IMS context. Finally, criteria are discussed that can be derived from the
experience of international R&D cooperation in other areas.
I. Introduction

I.1. Background

In mid-1997, the European Industrial Advisory Group (EIAG) which oversees European participation in the Intelligent Manufacturing Systems (IMS) international R&D co-operation initiative, expressed the need for an overview of the Strengths and Weaknesses of manufacturing industry in Europe (mfg-E), as well as a forward looking assessment of the Opportunities and Threats it faces. Such a ‘SWOT’ overview, it was felt, was one of the necessary inputs which would help the EIAG to identify elements of a European strategy for how best to modulate European industry’s use of the IMS initiative.

The European Secretariat for IMS, run jointly by DG.III.F and DG.XII.C of the European Commission, engaged the IPTS to produce the overview.

I.2. Interpretation of the specification

In response, the IPTS interpreted the request as an essentially stock-taking exercise to provide as complete and up-to-date a picture as possible of where European manufacturing industry’s technological capabilities and deficiencies lie at present, and with respect to its future survival and development. In terms of tailoring the study to the ultimate ‘strategy’ purpose it should serve, this interpretation involved an implicit restriction of the ‘strategy’ spectrum to issues to do with the thematic scope and coverage that should limit the subjects and research problems tackled in IMS projects involving European companies. Although in what follows below there is mention of some other issues (such as technology transfer, SME participation, etc.,) that would come under consideration from the point of view of ‘project-implementation strategy’, these were not frontline considerations from the outset.

The study proposal suggested segmenting the SWOT overview into two parts:

- The first was to be a SWOT overview of the general competitiveness of manufacturing industry in Europe, in terms of factors such as trade performance, value-added, market presence, technology balance of payments, etc.
- The second part was to be a SWOT overview of the ‘technological’ dimension of mfg-E. The aim was to make the technology overview from the point of view of both the ‘knowledge infrastructure’ available to mfg-E (Universities, research centres, etc.), as well as the situation, capabilities and prospects ‘internal’ to firms. Furthermore, it was proposed to shed light on Europe’s technological situation from both ’soft’ and ‘hard’ technology perspectives. This is in recognition of the
increasing importance and attention which commentators and analysts give to investment and development of soft technological competencies such as design, organisational innovation, knowledge-management techniques & routines, external logistics, etc.

The hope was that in confronting the results of these two components of the overview, however partial they might be, some interesting insights would be generated (such as unexpected mis-matches, synergies or strengths, etc.) which would have a particular relevance and utility for the strategy discussions of the EIAG.

I.3. Approach and methodology

From the outset, the idea was that the work should not involve any original research in the sense of collection of primary data, interviews, or the like, but that it should depend exclusively on whatever studies, reports and compilations of statistics could be readily accessed in the time allocated. Even so, the total of 35 person-days allocated to the work was quite modest. To help make up for this, some additional resources were reserved for two workshops to take place in the course of the study, with a number of objectives in mind:

- One objective was to provide occasions for review and discussion of draft parts of the overview produced by the two sub-contractors engaged by the IPTS (i.e. the Irish Productivity Centre for the general ‘competitiveness’ SWOT overview and Cranfield University for the ‘technological’ SWOT overview).
- A second objective was to provide a mechanism with which to extend the information base of the project by inviting a group of knowledgeable experts to take part in the workshops, and in particular to provide comments, further material and publication references relevant to the task of the study, which the sub-contractors might not have been aware of.
- A third objective of the workshops was to provide the occasion for members of the EIAG and the EU IMS secretariat to follow at close hand the development of the work, and to provide their comments and input as necessary, as things progressed.

Taken together, these objectives were an attempt to ensure an efficient study and introduce an interactive element to the work which would facilitate the eventual up-take of the final results by the EIAG.
II. IMS framework

The IMS is an international global initiative in Research and Technological Development (RTD) co-operation in the domain of advanced manufacturing. It provides a means for establishing partnership to share costs and risks in RTD, to combine complementary skills/technologies and accelerate progress.

Five issues drive this initiative:

- **globalisation**: locating production close to markets helps to reduce exchange rate risks, and to soften trade imbalances. Globalisation is inhibited by such factors as technology differences with respect to norms, standards and cultures.
- **the changing labour environment**: manufacturing is adversely affected by an increasing shortage of our best technicians who prefer careers in other parts of the economy. Action is required to improve the attractiveness of manufacturing industry.
- **the changing market environment**: consumer demand is becoming increasingly diversified and sophisticated, and the pace of change is increasing. Action is needed to accelerate product development and reduce time to market.
- **environmental issues**: priorities must include the protection and improvement of the global environment through measures such as efficient utilisation of resources and recycling.
- **the spiralling cost and complexity of R&D**: the increasingly large-scale nature of complex R&D projects is getting beyond the scope of single enterprises, or is seen as a wasteful use of resources. International collaboration of companies, public sector research institutions and academia is needed.

The coverage breadth of this international R&D co-operation is as broad as practicable and proposals for projects follow a bottom-up approach, based upon the following principles:

- contributions to, and benefits from, such co-operation should be equitable and balanced,
- projects must have industrial relevance,
- projects are carried out by inter-regional, geographically distributed consortia,
- collaborative projects can occur throughout the full innovation cycle,
- results of projects are shared through a process of controlled information diffusion that protects and equitably allocates any intellectual property rights created or furnished during co-operation,
- IMS project activities under government sponsorship or utilising government resources should not involve competitive R&D.

1 This section describes only the elements of the IMS programme that are considered relevant to the purpose of this study.
Project proposals must be consistent with the above principles, with the structure of the programme, and with the IPR provisions set forth in the IMS terms of reference. Accordingly, the project selection criteria are:

- industrial relevance,
- scientific and technical merit,
- added value,
- adoption and commercialisation potential,
- compliance with the selected technical themes (outlined below) and the IPR provisions, as may be amended from time to time by the international IMS steering committee.

The IMS terms of reference include five technical themes to start the full-scale implementation of the IMS programme:

- **total product life cycle issues**: manufacturing systems architectures, communication networks, environmental protection, minimum use of energy and material, recyclability and refurbishment, economic justification methods,
- **process issues**: clean manufacturing, energy efficiency, technology innovation, flexibility and autonomy of processing modules, inter-functional co-ordination,
- **strategy/planning/design tools**: business process reengineering, manufacturing systems modelling and simulation, manufacturing process design tools,
- **human/organisational/social issues**: education, training, corporate memory, new organisational paradigms,
- **virtual/extended enterprise issues**: information processes, logistics, architecture, risk assessment, multi-organisation teams.

Other themes may be envisaged. However, it should be ensured that new technical themes are consistent with government policies and industrial priorities of participants.

Furthermore, provisions for supporting SMEs, universities and research institutes have been explicitly established in the IMS programme.
III. EU Policy Context

As an integral part of EU RTD policy, participation in the IMS initiative should be fully compatible with its principles and coherent and complementary with other EU policies. This means that the IMS implementation should pursue the double objective of EU RTD policy - namely to strengthen the international competitiveness of EU industry, and to support other EU policies. It should also comply with the fundamental principles of subsidiarity, coherence and effectiveness, and simultaneously meet the criteria, value added, social objectives, economic development and scientific and technological prospects, established in the RTD framework programme.

In this context, IMS is concerned with the following objectives of the EU policy for international co-operation in RTD:

- to strengthen international competitiveness of EU industry and to develop technologies for future markets,
- to facilitate access for European research centres and organisations to scientific and technological knowledge available outside the EU,
- to share S&T information and to contribute to developing megascience and leading-edge technologies,
- to share responsibility and action to respond to global issues,
- to increase industrial participation to international S&T co-operation,
- to provide conditions for optimising benefits from international R&D co-operation, ensuring a fair balance between co-operation and competition relations with foreign companies,
- to support other EU policies, namely industrial policy and external relations policies.

IMS implementation should also be aligned with the new orientation proposed for the 5th RTD framework programme (FPV), in terms of rationalisation of resources, priorities and increased focus on specific future society needs.

Within the framework programme, IMS is concerned with the objectives of the second activity of FPV, confirming the international role of Community research, as a specific action implemented through a multilateral R&D co-operation agreement. This requires close co-ordination with the programme’s first activity, which shares many technical objectives with IMS. In particular, theme 3 on promoting competitive and sustainable growth and the key action innovative products, processes, organisations. In addition, IMS is fully concerned with the objectives and horizontal themes of the third and fourth activities, where the specific actions devoted to promotion of innovation, encouraging SME participation and improving the human research potential require special attention throughout IMS implementation.
Moreover, since a main motivation for IMS regards the rationalisation and optimisation of R&D efforts, it is important to co-ordinate IMS with other actions at international, European and national levels, in order to avoid duplication of efforts and to stimulate synergies.

In particular, it is important to consider the co-operative research carried out in the frame of Pan-European research networks and organisations such as COST, EUREKA, CERN, ESA, EMBL, ESO, ESF. The IMS programme should look for complementarity with those activities, especially with EUREKA’s industrial approach seeking competitiveness and productivity and with related collaborative research within COST.

Another example of international co-operation, with which IMS should be compatible, is the *Joint International Development of Civil Aircraft*. Like IMS, this action is undertaken jointly by firms from several participating countries with government support, and aims at sharing the large financial and technological risks involved in aircraft development.

Another point of attention regards the international activity on standardisation given the central role of standards for the IMS programme. Standardisation plays an important function in trade, commerce and technology transfer, and it becomes increasingly important to integrate the perspectives of the *standards environment* as early as possible into the definition of research projects. At the European level, IMS implementation should seek complementarity with the activities carried out within the European standards organisation (CEN) and its new action regarding standardisation and research links (CENSTAR) which aims to develop and promote more efficient link between European co-operative R&D and standardisation. At the international level, IMS has to take into account the activities of the main standards organisations such as ISO, IEC an ITU (general, electrotechnical and telecommunication associations).
IV. Manufacturing Industry in Europe: Strengths, Weaknesses, Opportunities, Threats

The following summary of main points has been prepared on the basis of the input received from the two sub-contractors, the complete versions of which are in the annexes to this report. Where relevant, other information and comments have been included, citing the source accordingly. The first two sections reflect the originally proposed decomposition of the SWOT attempt into two parts. The third section (IV.3) represents a summary of relevant points extracted from a summary of the main highlights of the recently made available Second European Report on S&T Indicators 1997 (see http://europa.eu.int/comm/dg12/press/1998/pr0804e1.html) of the European Commission.

IV.1. General competitiveness perspective

1. Since the beginning of the 80s, growth in value-added of mfg-E has been the slowest in the triad, stagnating in the early to mid-nineties, and complemented by a steep decline in manufacturing employment. This is consistent with the large negative balance for the EU in manufacturing industry FDI (e.g. for 1994 outward mfgFDI: close to 30 billion US$; inward mfgFDI: 17-18 billion US$), with the EU accounting for by far the biggest proportion of outward FDI in the triad. Some of this represents delocalisation of manufacturing activities of European companies to other regions.

2. In terms of high-, medium- and low-tech. industries (OECD definitions), the percentage break-down of value-added is approximately the same in each triad member, though for the EU the high-tech. proportion is the lowest in percentage value and growth rate. EU productivity levels in high-tech. lag those of the US which bears a relationship with the 2 % rise in high tech. employment in the EU in the decade to 1994, as opposed to the 20 % decline in the US, with a corresponding 2 % rise in output for the two regions.

3. Export/import data corroborate the analysis of high-tech. weakness of mfg-E with respect to its triad competitors, even if it still retains a significant proportion of world markets. This weakness is also characterised by a lower level of strategic alliances involving European companies, compared to their US and Japanese counterparts, although this difference is receding (see IV.3 below). EU strengths lie in medium- and low-tech. industries for which the proportion of its exports are respectively 40 % and 36 %. These will be required to remain strong features of mfg-E in relation to intra-EU trade which accounts for most mfg-E output.

4. Looking at strengths and weaknesses on the basis of demand structure leads to the following assessments:
• **capital goods:** Japan has eroded EU and US traditional strengths via improvements in design, performance validation, lead times; engineering skill depth, and mastery of logistics & co-ordination, represent EU strengths and an opportunity for responding to increased sophistication requirements of fabrication operations; EU has strengths in environmental compliance and related standards setting.

• **fast moving consumer goods:** There is an important mfg-E presence in specialised premium niches, for which high-tech. enabling capabilities need to be retained and enhanced; mfg-E strong in sophisticated food processing and packaging; weakness is found in slow adoption of innovative ICT systems to manage whole demand-production-distribution cycles.

• **staple commodities:** Strong experience and capacity; opportunity and challenge to increase product differentiation and process control & flexibility; danger of a loss of tacit knowledge and industrial know-how through reorganisation and restructuring.

5. A benchmarking study (in terms of six parameters: TQM, concurrent engineering, lean production, manufacturing systems, intra- and inter-company logistics, and organisation & culture) of 650 manufacturing plants from four EU countries (D, NL, UK, FI) and from a broad range of manufacturing sectors (Voss, 1995), shows how light can be shed on mfg-E strengths and weaknesses in a way which the aggregate economic statistics cannot do, e.g.:

• Only 14 out of 650 sites were considered world-class with > 30% considered vulnerable.

• Foreign-owned firms fared better than domestic ones, in both practice and performance (Japanese-owned), and average performance (American-owned).

• Domestically-owned firms were significantly better at new product development.

• examples cited of areas where the world-class challenge was being met included the **German textile industry**, the **UK electronic components industry** and **restructured sites in former East Germany**.

6. The competitive threats which the short-term future holds for mfg-E include the ability of other developed economies to deliver customisation to the market and sustain the required long-term investment and development efforts. Another threat lies in Europe’s demonstrated inefficiency in exploiting research results, partly due to a lack of attention to detail in the development and implementation stages.

7. Other threats bearing on mfg-E include the loss of knowledge capital through downsizing in response to short-term dictates of financial markets, or slow adaptation of new forms of work organisation because of labour market rigidities.

8. The prime source of opportunity for mfg-E, and indeed for industry in all developed economies, will come from the incorporation of knowledge and service value-added into products.
IV.2. Technology perspective

1. The standard S&T indicators which are readily available at EU level - e.g. patent and publications data - show the familiar story of a strong European basic-science R&D system, with a rather weak rate of innovation and exploitation. Patent data corroborate the acknowledged weakness of mfg-E in computers and electronics as well as the relative strength in chemicals, pharmaceuticals, aerospace and motor vehicles.

2. However, rather than doing the technology SWOT synthesis of mfg-E and the European knowledge infrastructure on the basis of patent and bibliometric/citation data using the standard sector and discipline classifications, it was decided to take an exploratory venture through the literature on the basis of a broad definition of ‘technology’ in which an equal emphasis was given to hard and soft components, attempting a prior clarification of the definition possibilities (see annex II).

3. The most interesting literature which the study examined in this context, were the reports of a number of national technology foresight exercises (France, UK, Germany, The Netherlands). Such foresight studies do not fall into a well defined and unique format - quite the contrary - but they do share the common characteristic of combining in a coherent manner, a stock-taking exercise of technological/business Strengths and Weaknesses, and a structured assessment of future technological Opportunities and Threats, which is precisely the orientation of this study.

4. The national foresight exercises, in many cases go beyond a SWOT-type stage, to the determining of priorities for action which is tantamount to identifying national technology strategy options. This was the case in the French 100 Key Industrial Technologies, the UK Foresight Programme and the Dutch Technology Radar exercise.

5. Two further features of these foresight exercises which coincide with the aims of this study include:
   - the specification of Soft Technologies as one of the ten principle classification areas for the 100 Key Technologies exercise (F); and
   - the explicit matching of the critical technological needs expressed by Dutch industry with the capabilities and competencies residing in the Dutch knowledge infrastructure (public and private research establishments, universities, etc.)

6. The detailed results of these national exercises, are clearly not automatically extrapolable beyond the boundaries of the individual Member States, but they are
interesting and relevant, if only to illustrate the type of conclusions which might be reached, were a similar EU level exercise undertaken.

7. Some of the priority soft technologies identified in the French exercise, for example, together with estimates of the relative positions of Europe in terms of scientific and industrial capability (which, moreover, also reflects a concern for the matching of industrial capability and the capabilities residing in the knowledge infrastructure), were:

- *value & functional analysis, and ‘cost-constrained objective’ (CCO) project management*: European scientific and industrial positions both deemed ‘average’
- *sensorial metrology*: European scientific and industrial positions deemed respectively ‘average’ and ‘weak’.
- *concurrent engineering*: European scientific and industrial positions deemed respectively ‘weak’ and ‘average’
- *application of real-time management of logistics information to stock-flows*: European scientific and industrial positions both deemed ‘average’
- *ergonomics of work-stations and professional products*: European scientific and industrial positions deemed respectively ‘average’ and ‘strong’

8. The Dutch Technology Radar exercise identified 15 strategic technologies (bioprocesses, catalysis, data & knowledge systems, composites, polymers, energy saving, gene technology, measurement & process control, mechatronics, sensors & actuators, production automation, separation, software, surface treatment, interactive multimedia applications) and assessed the match/mismatch with the accessible knowledge infrastructure in terms of the following factors (The following also indicates some of the weaknesses detected):

- *quality of new researchers*: low multidisciplinarity training and combination of technical-business skills
- *quantity of university graduates*: falling numbers in technical areas, especially computer science, IT and electrical engineering
- *fragmentation of university research*: too dispersed and not responsive to technological change
- *university responsiveness and multidisciplinarity*: organisation and course content not responsive to changing needs
- *articulation of the needs of industry*: lack of clear signals from industry (especially SMEs) to universities.

9. Regarding the diversity of innovation systems from the point of view of the knowledge infrastructure, the following is taken from another IPTS study-report under preparation entitled: *An analytical scheme for benchmarking innovation practices of European firms: A synthesis* (Bobe & Bobe, 1998) which illustrates some specific features of Germany, the UK and France:
• **Germany** is characterised by very good technological universities both for training and for research, and is richly endowed with “bridging” institutions such as the Fraunhofer Gesellschaft, or the Steinbeis Foundation;  

• **The United Kingdom** is characterised by good universities, a low number of engineering students, an unbalanced workforce in terms of skills/qualifications with a long tail of poorly trained workers; furthermore, there are few “bridging” institutions;  

• **France** is characterised by very good engineering schools and a good number of students in science and technology; it suffers from the double dichotomy between, on one hand large research organisations and higher education institutions, and on the other, between good research universities and engineering schools with weak research activities; bridging institutions lack efficiency.

10. On the basis of the information uncovered in the allocated time, the objective specified at the outset, of obtaining an outline European-level technology SWOT overview for mfg-E structured with respect to two axes: **industry<->knowledge infrastructure** and **hard<->soft technologies**, has proved elusive. However, this has served to flag an information gap which might best be filled by some comprehensive undertaking in this area at EU level.

IV.3. **R&D, innovation & competitiveness**

1. There is some evidence to support the so-called European Paradox - that the EU’s healthy performance in scientific research is not being translated into strong technological and economic performance - but the picture varies across different member states and industries. Moreover, a new paradox emerges: **Europe’s exports of high-tech goods are growing rapidly, in spite of its rather moderate technological return on investment.**

• The EU performs well compared with Japan and the US in terms of its scientific output (publications), but its technological return (patents divided by business R&D expenditure) is less impressive, falling well below the US and Japan in terms of US patents, and above the US and Japan in European patents - but with the US rapidly closing the gap.  

• Significant differences are observed between Member States. The paradox is most clearly confirmed for **Belgium, Greece, Spain, Sweden and UK**, countries with high scientific output, but below average technological returns on investment. The best performers are **Denmark, Finland and the Netherlands**, which boast high levels of both patent and publication output.  

• The picture also varies by sector. In certain industries (**computers, electronics, pharmaceuticals**) Europe obtains substantially fewer patents per unit of

---

business R&D expenditure than its competitors, while chemicals and motor vehicles are sectors which yield relatively good returns for the EU.

- In high-tech trade there is another paradox. In spite of its very modest performance in technological output, the EU’s exports of high-tech products are found have grown rapidly during the 1990s, notably in computer and electronics products with much of the export rise being attributable to the Netherlands and UK. This could be due to re-exportation or intra-firm trade in multinational groups.

2. Multinationals continue to play a major role both in employment and in R&D expenditure. However, unlike their US counterparts who are now creating employment, EU multinationals have been shedding jobs much faster than the sectoral average.

- In 1995 the European, US and Japanese multinationals whose main activity was in the aerospace industry accounted for 31% of R&D expenditure and 65% of the jobs in this sector. In the IT-related industries, the giants account for more than 40% of total spending on R&D, but provided less than 40% of the jobs. In the automotive industry they were responsible for 80% of the total R&D spend, but less than 60% of the employment.

- In employment, the leading European multinationals are shedding jobs much faster than the sectoral average, especially in pharmaceuticals (- 8 % p.a.), computers (- 9 %) and aerospace (- 11 %). However, in the US the picture is reversed. The period of downsizing and restructuring is now over, and the multinationals are now creating jobs, particularly in those industries where sectoral employment is falling.

- While Japanese multinationals appear to be increasing their emphasis on research, it seems that European multinationals are publishing less than their US counterparts and are focusing more on patenting, i.e. development, activities. This publication-patent gap suggests that basic science in Europe is still being driven by universities and public research institutes, and therefore that there may be a need to improve the interface between university and industry.

3. The increasing globalisation of technology is reflected in the growing number of international technology alliances. Technology alliances have become as important as R&D competition. Europe is a leading world-wide partner in the formation of these alliances along with Japan and the US.

- A technology-based alliance consists of an agreement in which two or more firms unite to pursue a set of agreed goals while retaining their strategic autonomy.

- Technology-based alliances are an international phenomenon. For every national alliance, there are on average 1.31 international ones. More than 65% of such
international alliances since 1980 relate to three new core technologies: information technology, biotechnology and new materials.

• The EU is not lagging behind the other major economic systems in its propensity for forming technology-based alliances. The total number of EU alliances grew from 646 in the period 1988-1991 to 1718 in the period 1992-1995, an increase of 270%. In the same period, the NAFTA total grew from 1958 to 5618 (290 %) and the DAE total from 574 to 1394 (240 %).

• Only one-third of alliances are within the same industry, while two-thirds are set up by firms that belong to different industries. One can therefore conclude that alliances are primarily established to combine different technological skills, and only in the second instance to share R&D costs (within-industry alliances).
V. Discussion of Options for a European IMS Strategy

To begin this discussion, it is important to bear in mind the constraints and boundary conditions which the established IMS criteria framework and EU RTD policy place on it. The most salient points of relevance have been summarised for each of these in previous sections (II & III). Secondly, it must be recognised that the results of the attempted SWOT overview summarised above in IV, are of general use and relevance to the discussion of strategic options, but of limited use for any ‘detailed’ specification. Nonetheless, the following represents an attempt to scan a number of options, invoking in the process other information and perspectives when relevant and available, in complement to what has been summarised above.

V.1. General strategy considerations in the IMS context

1. The R&D purpose of IMS clearly places the time-horizon for strategy considerations on the medium to long term, beyond the immediate short-term business cycle time frame. The main relevant trends and issues affecting manufacturing on this time scale, are the same across all the developed world and include:

   • increasing extent of globalisation, affecting more and more of the business functions;
   • spiralling cost and complexity of new product development;
   • the increasing criticality of customer orientation and the need to solve the ‘customer paradox’ whereby consistent quality increases have been accompanied by declining customer satisfaction (Deloitte & Touche: 1998 Vision in Manufacturing);
   • the increasing importance of intangible investments.

2. Another important macroeconomic consideration to bear in mind is the declining importance of manufacturing throughout the OECD in terms of its share of output, the proportion of employment it accounts for, etc. This is as much due to rapid productivity growth, cost-cutting, price-lowering and less material intensity in high-tech sectors serving growing markets, as it is to sectors which are in decline in more absolute terms.

3. Even for areas of manufacturing where markets in the developed world are stagnating, tremendous prospects lie in the developing world, with the so-called ‘big five’ (China, Brazil, India, Indonesia and Russia) foremost in the sights of firms seeking increased business.

4. The multiplicity and variability of distinctly ‘national’ innovation systems which typify the European scene, and which have a direct bearing on the corresponding industrial structures, frustrates a meaningful and straight-forward discussion of
overall EU strengths and weaknesses, though does not render it \textit{a priori} impossible. The national foresight exercises constitute the type of priority- and strategy-setting activity that could find its analogy at EU level. However, the type of strategy-setting associated with national or regional foresight exercises is premised on a broadly based ‘offensive’ drive to raise its own territorial technological competitiveness. For IMS purposes, where there is the added condition of international co-operation in the R&D activities undertaken, the relevant strategy can at most, be a sub-set of the overall foresight-derived strategy.

V.2. Strategy-setting approach and options

V.2.1. An integrated strategy?
To start with, the question is raised regarding the extent to which an ‘integrated’ strategy-type approach is appropriate as an overall option for a European IMS strategy, and if so, how to combine this with other strategic elements? By integrated is meant an approach which has characterised in the past certain national industrial sector or ‘mission-oriented’ technology-policy approaches where, in a very focused way, all or many relevant aspects of a given technological problem, issue or large scale project objective can be addressed coherently, and with a critical mass sufficient to ensure a major sector-wide impact and knock-on effects farther afield, if successfully implemented.

How can elements of such a strategy be operationalised and combined with the bottom-up conception and principles of IMS implementation and the EU RTD Framework Programme? Is it in fact desirable to do so, or should the strategy just tune itself to a straight-forward project-by-project implementation approach? It is worthwhile pointing out in this context how the implementation of the EU RTD Framework programme has evolved in the direction of achieving more focus, more integration and more critical mass. This has been anticipated to some degree by innovative attempts to achieve integration and higher critical mass in grouping projects under some of the ‘Specific’ EU RTD programmes, from which some ‘best practice’ elements or relevant lessons might be picked up for the IMS strategy, and quite possibly be an area where Europe is ahead of other participating regions.

The danger to be borne in mind is of situations where the sectoral specificity and support can lead to real or perceived distortions of competition, and the political fall-out which can arise from this.

V.2.2. Criteria-based strategy options
The following proposes that the EIAG IMS strategy-setting discussion aim to identify and use different criteria sets in the manner of selection filters and/or evaluation measures against which one can screen submitted IMS R&D proposals. Some of the criteria sets will constitute clear GO/NO-GO eligibility conditions, while others can be more fuzzy in nature requiring judgmental assessments.

Following this approach, the strategy will be determined by: the choice of criteria sets; the strictness of their application; and the way in which the different sets are combined - either in series (in a logical ‘x’ AND ‘y’ sense) or in parallel (in a logical ‘x’ OR ‘y’ sense), or mixtures of both.

The following paragraphs discuss some of the options and approaches, indicating, where, in our opinion, are the advantages and drawbacks of each, without being prescriptive.

1. IMS and RTD Framework Programme: Heretofore, the conditions for eligibility and evaluation as specified at a certain level of generality by IMS and the relevant EU Specific RTD Programmes (e.g. for IMS these include industrial relevance, compliance with technical themes (i.e. total product life cycle, process issues, strategy/planning/design tools, human/organisational/social issues, virtual/extended enterprise), S&T merit, commercialisation potential, IPR rules compliance, added value), constitute the first fixed set of criteria from which to compose the strategy.

For the purpose of this discussion we take it as a ‘given’ that these and similar framing conditions and criteria have been operationalised already in a way that is not now to be called into question.

Other criteria sets adopted will serve to give a narrower strategic focus under the broad frame.

2. Sectoral discrimination: This implies making a strategic choice to limit the IMS initiative to industries from certain sectors or certain types of sectors. The types of classifications typically used to group individual industrial sectors into larger categories (defined by the OECD) include:

   **technology content** (based on R&D intensity)
   - high tech. (aerospace, computers, pharmaceuticals, instruments,..)
   - medium tech. (chemicals, motor vehicles, plastics, non-ferrous metals, ..)
   - low tech. (food, textiles, wood products, iron & steel, petroleum refining, ..)

   **orientation** (based on the primary competitiveness factor)
   - resource intensive (food, wood, refining, ..)
   - labour intensive (textiles, metal products,..)
   - specialised supplier (elec. and non-elec. machinery, communications equip., ..)
- scale intensive (paper, chemicals, motor vehicles, ..)
- science based (aerospace, computers, pharmaceuticals, ..)

**wages** (based on average hourly wage)
- high wage (> 15% above the median)
- medium wage
- low wage (> 15% below the median).

Apart from the discussion contained in annex I in terms of technology content (high tech., etc.), another interesting discussion of growth in value-added, apparent consumption and in employment for each of the three segmentations above, comparing the established economies with the maturing and developing economies, can be found in the 1997 Panorama of EU Industry in a special feature *Analysing Growth Markets* (European Commission DG III, 1997).

The utility of such an approach lies in testing the validity of macro-economic level hypotheses such as whether or not high value added is more or less synonymous with high technology, or whether high R&D expenditure or inflows of FDI, accelerates / increase economic growth. However, it is very difficult to use these analyses and segmentations as a basis for a differentiated strategic focusing of IMS to a limited sub-set of industries, for a number of reasons:

1. The tendency to favour medium-high tech./science based - specialised supplier/high wage categories, ignores the fact that the aggregate statistics hide a wealth of information, such as regional and national specialities and certain high-tech, high-growth niches within what are nominally, at aggregate EU level, low-tech, low value-added industries. Think of the fashion and luxury goods industries in France and Italy, or the findings of the benchmarking study mentioned of the world-class positions of German textiles and UK electronic components.

2. Notwithstanding the importance of globalisation, foreign trade, and the criticality of global-market presence as a vital competitiveness benchmark, the bulk of mfg-E’s output is consumed in the internal market. There is considerable sense, in this regard, in having a non-discriminatory strategy, in favour of the maintenance of a modernised and competent manufacturing industry presence in Europe over all sectors - albeit commensurate with the prevailing framework conditions, corresponding to the structure of European demand, as well as commanding shares of world markets, irrespective of the statistical categories.

3. **Growth Products:** A different manner of segmenting manufacturing industry which has been used by researchers to explore the concept of a ‘good’ export specialisation pattern, is on the basis of the export growth pattern of product groups. Studying 60
product groups (using the IKE Trade Database) over the period 1961 to 1994, Dalum, Laursen & Villumsen from IKE Group, Aalborg University (DK), divide their sample into three groups of twenty, which they label high-, medium- and low-growth groups, with a further three-way sub-division of the high-growth group as follows:

1. **high and increasing** growth rates: whose share of OECD exports grew from 2.6 % in 1961 to 10.7 % in 1994 (of which **ICTs - semiconductors, computers, telecommunications** were respectively 1.8 % and 8.9 %). The remaining parts are accounted for by **orthopaedic equipment & hearing aids, electromedical equipment, non-electrical medical equipment, and measuring & control instruments**.

2. **high but decreasing** growth rates: share of OECD exports - from 11.5 %:1961 to 22.5 %:1994, **including furniture, plastics, motor vehicles** (accounting for > 50 % of the group in 1994), **organic chemicals, clothing, and other non-electrical equipment**.

3. **new high growers**: i.e. products which were not high growers between 1961 & 1973, but thereafter were. Its share of OECD exports increased from 13.4 %:1961 to 19.7 %:1994, and includes **machinery for production and distribution of electricity, other electrical equipment, pharmaceuticals, pumps and non-dairy centrifuges, photographic & optical goods & watches, power generators, and a mixed rest-group of manufacturers**.

The work in question goes into a detailed discussion comparing data among triad members as well as looking at the variability of the figures across individual European countries.

However, the point here is not to suggest that this detailed analysis could be used to set up a product-based set of discriminating criteria, in a way that was already rejected in the previous paragraph. The suggestion is made, however, that some minimum **common sense** criterion be introduced to discriminate out R&D projects relevant to industries producing ‘dead-end’ products where the market has irrevocably stagnated or entered into decline because of technological progress (electro-mechanical office machinery, ship-building), or because of the rise of environmental concerns (natural resource intensive products - iron ore, textile fibres), or some other set of circumstances.

**4. Key technologies**: The possibility exists of limiting the EU IMS strategy to projects which address one or other technology from a hypothetical list of European Key Technologies. As mentioned above, such lists have been generated by a number of national technology foresight exercises, but that no EU-wide foresight exercise has yet been attempted. Annex II lists the complete list of 136 technologies identified in the French key technologies exercise. In the recent Second European Report on S&T Indicators, this same list was used as the basis for a detailed analysis of European
performance in S&T. For this they clustered 88 of the technologies into the following 10 areas, with special attention paid to a sub-set of 24:

- **Electrical & electronic components** (batteries for portable electrical equipment; conception & fabrication of low consumption components; electrical vehicles)
- **Audiovisual-Telecommunications** (flat screens, broad band transmission & switching, management of intelligent networks)
- **Computers**
- **Instruments-Optics** (optical fibre cables, robotics for hostile environments)
- **Pharmaceuticals-Drugs** (vaccines from genetic engineering, recombinant drugs, monoclonal antibodies)
- **Biotechnologies** (DNA sequencing, genetic modification of plants, production of recombinant proteins)
- **Materials** (aluminium/ magnesium structures for cars, piezoelectric, ferroelectric and magnetic polymers, membrane separation technologies,)
- **Industrial Processes** (polymer recycling, new organic matrix materials)
- **Environmental Processes** (biological water and sludge treatment, water treatment and drinking water quality control)
- **Transport** (improvement in the recyclability of cars).

The 15 strategic technologies identified by the Dutch Technology Radar exercise (bioprocesses, catalysis, data & knowledge systems, composites, polymers, energy saving, gene technology, measurement & process control, mechatronics, sensors & actuators, production automation, separation, software, surface treatment, interactive multimedia applications), (Dutch Ministry of Economic Affairs, 1998) were selected from a list of 46 ‘important’ technologies which were grouped into nine technology clusters:

- process technology
- biotechnology
- materials
- discrete production
- plastics moulding
- energy
- opto- & microelectronics
- I&CTs
- civil engineering technologies.

Using these cluster themes, the same Dutch exercise also produced coherent combination of lists of strategic technologies from eight different national foresight reports (US, Japan, Germany, UK, F). Because of the heterogeneity of these lists, the compilation was made using a taxonomy of five hierarchical levels:
1. 16 Technology clusters (adding one to the above list application-oriented technologies)
2. 50 Technology fields (e.g. separation technologies; production automation technologies)
3. 90 Technology categories (e.g. pollution control; discrete product manufacturing)
4. 180 Technology sub-categories (e.g. ultrapure refining methods; equipment interoperability)
5. 430 Examples of specific technologies or applications (e.g. electron beam processing; data-driven management info systems)

The result of this is a very long list of technological themes and sub-themes. The compiled list also records the reasons given why the technology sub-categories were considered important in terms of contribution to economic development, or social needs.

The relevant question for this study to address is whether or not these key technology lists could be of some use in fixing an EU IMS strategy.

- One possibility would be to make a selection of the aggregate categories which have most to do with manufacturing (such as materials and industrial processes, from the French list, or discrete production from the Dutch list), and use the individual technologies listed under the chosen categories as a further set of focusing criteria for the IMS strategy. This is premised on the supposition that the concept of key or critical is as valid at the EU as at the corresponding national levels, which is not necessarily the case.

- Another different possibility would be to make a selection of the key technologies from one or other list, as a function of their relevance to the five main groupings into which the IMS technical framework is divided.

Leaving aside the question of the validity of the national “key” technologies at EU level, it is important to point out that the key technology lists are predominated by so-called ‘hard’ technologies, which begs for an analogous criteria set to be applied in parallel, which identifies key areas of ‘soft’ technology to form part of the IMS strategy. (This aspect will be addressed below following the next paragraph.)

5. Key technology selection criteria: To complement the lists of key technologies just presented, it is also instructive to consider the criteria which the various national foresight exercises used in identifying the key ‘strategic’ technologies out of much longer initial lists.

France - The French key technologies were selected by scoring individual technologies against three criteria sets, on a scale of one to four for each criterion:
- five feasibility criteria (existence of industrial & scientific competence; mastery of the associated technologies; existence of a favourable environment; existence of capable partnerships; capacity to exploit the technology)
- five attractiveness criteria (present & future economic potential; interest in acquiring or maintaining a competitive position; offsetting a vulnerability; contribution to national needs; potential for diffusion through the national industry)
- five key success factors (expressed wish by concerned actors; existence of a leader; possibilities for alliances; sensitivity to public initiatives; social acceptability).

UK - The UK foresight exercise also determined its generic priority areas using sets of feasibility and attractiveness criteria (OST-UK, 1995).
The attractiveness set included sub-sets of criteria for A) the economic and social benefits that may be derived from a new market of technology opportunity, and B) the ability of the UK to capture the economic & social benefits ahead of other countries.
The feasibility set included sub-sets of criteria for A) the likelihood of scientific or technological breakthrough, and B) the strengths of the UK S&T base.

NL - The Dutch strategic technologies were determined by scoring the competitive advantage for each technology field using information gathered during interviews and expert knowledge, against its calculated economic value to the Dutch economy (EV(j)), i.e.

\[
EV(j) = |\sum i \text{GDP}(i)| \times |\sum i \text{R&D}(i)|
\]

where GDP(i) is the contribution of the business segment ‘i’ to the Dutch GDP and R&D(i) is the corrected expenditures on R&D made by the business segment ‘i’, and the sum is made over all the business segments ‘i’ for which technology ‘j’ is important. A total of 22 business segments were considered in this exercise.

It would not make sense to adopt for the IMS strategy the specific criteria used in these national foresight exercises. However, the idea of using the same simple feasibility versus attractiveness framework, but with more appropriate individual criteria, is something which could be considered. For example, a proposed scheme is described in annex II for dimensioning the relative attractiveness of IMS R&D projects based on a two-by-two matrix crossing (hard technology, soft technology) with (mobile technology, immobile technology), the mobility dimension being a measure of the relative ease of moving a given technology into or out of Europe. In this scheme, the
most attractive from an investment point of view are the soft-immobile technologies, and the least attractive the soft-mobile ones.

6. **Soft technologies**: In our view, the primary focus of the IMS strategy in terms of thematic scope or coverage as far as the participation of mfg-E is concerned, should be in the area of so-called soft technologies - i.e. technologies in the sense of ‘know-how, know-who, know-why’ such as production and general business strategy, design, quality and logistics, organisation of production and of human resources, knowledge management, techniques for market and techno-economic intelligence, and other ‘technologies’ which come under the label of intangible/ immaterial assets.

The reason for this is that these aspects have become increasingly determinant factors of competitiveness in the developed world (see, for example, the recent report by Deloitte & Touche *1998 Vision in Manufacturing: Global Report*), and they also represent an area of acknowledged European weakness. Because of the difficulty to measure these soft aspects, they are under-researched and under-considered in competitiveness surveys.

To quote an article in the 1997 Panorama of EU Industry on *Immaterial investment as an innovative factor* (European Commission DG III, 1997a):

> a virtually exclusive focus on the ‘hard’ technological components and limited indicators such as R&D investments, therefore results in a highly incomplete and partial approach of industrial and technological policy design.

Nonetheless, the forthcoming OECD 1998 Science, Technology and Industry Outlook, also points out that:

> Technology policy is also shifting from promoting innovation in “hard” to “soft” technology.

In fact, the specified IMS technical framework - the main groupings for which are: total product life cycle, process issues, strategy/planning/design tools, human/organisational/social issues, virtual/extended enterprise - is already dominated by ‘soft’ technological issues. However, given that an overview of the strengths and weaknesses of mfg-E for these issues has not been possible, a highly differentiated strategy focusing, for instance, on the most important European weaknesses, cannot be specified at a detailed level.

Nonetheless, some interesting literature does exist giving partial views such as the afore mentioned articles in the Panorama of EU Industry. There also exists a study report by the Swedish Institute for Management of Innovation and Technology (IMIT) on
International Transfer of Organisational Innovation (June 1996 - conducted in the frame of the European Innovation Monitoring System initiative) which makes the following assertions based on case-study work:

- diffusion of organisational innovation takes place later in Europe than in the US, meeting considerable resistance, in addition.
- organisational innovations do not diffuse from one European country to another.
- organisational innovations are transferred unilaterally from the US to individual European countries, firstly to American subsidiaries. Further diffusion is first via American consultancy companies to clients across Europe, and eventually picked up by European business schools and management training institutes.
- the study puts forward the idea that the European situation in this regard is paradoxical in that the great variety of European business contexts probably create more organisational innovations in Europe than in the US.

Obviously, these conclusions cannot be generalised to all areas of soft technology, and furthermore, they implicitly caution against blind acceptance of the assumption that US or Japanese best-practices are necessarily the best ones to adopt in Europe, thus perpetuating an eternally ‘follower’ strategy in this area. The implications of this in IMS strategy terms is not to assume across-the-board weakness of mfg-E in soft technologies in spite of the recognised deficiencies, but to allow for the inclusion of potential strengths in this area, amongst its bargaining cards when it comes to international co-operation and know-how trading.

Further work (still underway) which promises to generate, in due course, knowledge of relevance to the issue of this study, is a series of four EU-wide pilot benchmarking activities which attempt to uncover good practices comparing Europe with other parts of the world. The three themes of relevance to the soft technologies focus of IMS are:

- the coupling of ICTs and organisational innovations
- transport and logistics
- skills and training.

The difficulties of quantifying a lot of the information on these soft technological issues mentioned above, could probably best be tackled via some ad hoc benchmarking exercise conducted in the technology foresight vein.

7. International R&D co-operation #1 - general challenges: It is generally accepted that the increasing importance of international co-operation for companies is with respect to: a) accessing global technology and expertise; b) extending R&D capability through consortium leveraging; c) getting a broader exposure to the needs of international markets;
d) developing strategic capability, catching-up or diversifying; and e) levelling the competition playing field.

Literature reports indicate the increasing interest of European enterprises to participate in international R&D projects (P. de Woot, 1990; Second European Report on S&T Indicators, 1997). A survey of European firms and research organisations identified as their main incentives for international co-operation the **limited size of firms, complementarity in R&D skills, diversification of R&D, reinforcing the creativity of in-house R&D and indirect access to competitors know-how**; and as main disincentives the **risk of losing a tight control of the R&D process, and the confidentiality and secrecy issues**.

However, international co-operation is a relatively recent and complex phenomenon, the actual impact of which is very difficult to predict. It seems unclear whether the position of EU manufacturing industry with respect to its main competitors and its business culture can allow European enterprises to enter international co-operation without excessive risk.

There have been significant successes involving European enterprises in large research collaborative projects, such as in aviation, space or advanced research (Esprit, etc.). But it is not possible to extrapolate those experiences to the broad scope of the IMS programme.

Indeed, past experience shows that international co-operation does not systematically lead to win-win situations. Distortions can arise, due to the interactions with competition, which may even turn the potential benefits into significant disadvantages such as **loss of control or dominance**. On the other hand, competition interaction will always naturally occur, as part of the market dynamics. Therefore, it appears essential for international R&D co-operation to manage the ambiguity inherent in the competition/co-operation relationship and to ensure a fair balance between both.

In theory, the IMS programme contains the mechanisms to respond to the main issues of co-operation such as **reciprocity, exploitation of results and transparency**, and to assure an **equitable and balanced collaboration**. **However, in practice, due to the broad scope of IMS and to its bottom-up character it could prove difficult to verify that conditions in specific projects are not to Europe’s disadvantage.**

**Factors affecting international R&D:**
A study carried out by ENEA-CESPRI (Malerba, 1994) has characterised the factors affecting international R&D co-operation.
To explain the **demand factors**, it uses a conceptual framework based on firm-classification into four major groups according to their differences in technology characteristics (sources,
possibilities of appropriation, linkages with basic scientific research), the needs of users, and the types of technological trajectories, i.e.:

1. supplier-dominated firms (SD),
2. specialised-supplier firms (SS),
3. scale-intensive firms (SI) and
4. science-based firms (SB).

This classification points out three factors driving international R&D co-operation: *technology characteristics*, *localisation* and *external linkage* factors.

The *supply factors* are explained in terms of differences across countries regarding scientific and technological capabilities, which are linked to the structure and competences of the national systems of innovation.

Among the conclusions, the study indicates:

- general growth of expected collaborations with foreign partners
- growing importance of international R&D for firms co-operating in advanced technological areas, SB or SI firms (chemicals, telecommunications, electronics),
- Traditional sectors and SS firms show a low share of international co-operation,
- the growing importance of the interaction between new technologies and basic research is an incentive for SI and SB firms to open new technological windows through international co-operation,
- local specificity of the production system (such as for food sector) is an incentive for domestic R&D co-operation.

These conclusions are also verified at the sectoral level by a study commissioned by the EC, based on a sample of 129 contract research organisations (EC, 1989).

To a certain extent, these conclusions also correspond with other works which found a complementarity relationship between technology innovation and diffusion and a higher motivation for investing in innovation for technologies exhibiting higher R&D spending and spillover effects (OECD, 1992).

Summarising, these studies indicate that there are higher demand for international co-operation for firms and sectors which:

- use complex and science-based technologies,
- produce goods for the global market, and
- have network structures and greater number of links with external organisations.

Although there is insufficient experience with international co-operation, there seems to be a clear differentiation effect depending on the technology-type and characteristics. In the perspective of the IMS European implementation, the above discussion can be translated into a two-fold criterion:
• seek maximising benefits, by supporting sectors and organisations that have higher chances of succeeding in IMS consortia and that propose R&D projects with higher potential leverage effects (such as generic, emerging or interdisciplinary technologies),

• seek risk minimisation, by allocating lower priority to support projects from sectors and organisations that exhibit less success factors for international co-operation and where relative strengths may be to Europe disadvantage (such as traditional sectors, limited scope technologies or local specific production systems).

8. International R&D co-operation #2 - some specific themes: An essential limiting criterion for IMS, is that the research conducted address areas of critical future needs and opportunity where global/ international S&T collaboration is justified. Such areas, in general, go well beyond the scope of IMS - see for example the special issue of the journal “Technology in Society” Vol.19 No.1 (1997) devoted to global co-operation in science, engineering and medicine for a broad discussion of the subject. One of the articles in this publication (p. 61-65 by Geraldine Kenney-Wallace, McMaster University) singles out 12 topics of potential global impact in the event of business/ political leadership’s failure to take timely action. They are presented in terms of pre-competitive challenges in which the private sector, it is argued, has a major role to play, but with the added feature of high-risk or public good aspects on which the global co-operation could be premised. The ones which bear most relevance for manufacturing are indicated with an ‘*’ (although manufactured goods inevitably crop up in relation to all the listed themes):

1. *ICT & photonics driven technology fusion*, for the provision of the 21st century’s infrastructure, from multi-media to tele-medicine and tele-learning, the design of smart factories, smart cities, new global regulatory standards and protocols.

2. *Health issues*, such as new areas of medical technology fusion (e.g. lasers and cancer).

3. *Brain research*, neurological disorders, language and learning, ...

4. *Nuclear waste disposal*, monitoring, safe demolition of weapons, ...

5. *Mega science and engineering projects*, including space

6. *Natural disasters*, development of a global alert capability

7. *Water*, all aspects (except marine) from a global perspective


9. *Oceans*, pollution, toxic material transportation, fisheries health and management, marine engineering,...

10. *Environmental issues*, beyond the present globally organised effort on climate change, balanced with economic issues.
11. *Energy, economy and the environment*, science & engineering as well as economics and technology management
12. *Science & engineering at the limits*, high/low -temperature, -pressure, -vacuum, -size, -wavelength (energy), -time, -power. Efforts towards precision science and precision engineering; global standards, sensitivity for environmental measurements based on feasible, sensible measurements; regulatory limits; harmonisation of presently mis-matched technical standards which impact freer trade movements or present non-tariff barriers.

The option exists to use some of the above to limit the European strategy to issues which overlap with the IMS technical framework themes.

9. **Technology innovation and diffusion, and the role of SMEs**: Since poor performance in translating R&D capacity into strong technological developments is a well know European weakness, it is worthwhile bearing in mind the main issues underlying technology innovation and diffusion phenomena, and to extract lessons for effective SME involvement and IMS implementation (EC, 1997a):

- innovation and diffusion of technology are recognised as two interdependent interactive processes that can exhibit two extreme regimes: 1) a *vicious circle*, where technology innovation is inhibited by technology diffusion and therefore both are mutually substitutive (competitive); and in the other extreme, 2) a regime driven by catalysing conditions where increased technology diffusion enhances technology innovation entering a *virtuous circle* (co-operative). Past experience demonstrates that sectors having higher R&D expenditure show higher innovation-diffusion complementarity,
- the challenge for policymakers is to create conditions to stimulate *virtuous circles*, for instance by protecting technology innovation while stimulating its diffusion to maximise the indirect benefits (spillover),
- the critical factors lie in the diffusion process of non-incorporated technology, namely technology *spillover* and *absorption capacity* of enterprises. The *spillover* effects play an essential role in building formal and informal networks for knowledge propagation, whereas the *absorption capacity* of enterprises depends on the characteristics and complexity of the ‘transferable’ knowledge,
- technology specificity and localisation factors are determining characteristics of technology diffusion,
- technology diffusion and in particular development of absorption capacity demonstrates the double function of R&D to improve the ability of the enterprise to learn and anticipate future developments,
- technology diffusion is especially critical for SMEs that do not have significant R&D resources and therefore have to exploit *spillover* effects, e.g. through networks, and to build a learning and *absorption capacity*,

32
• SMEs play also a critical role as technology diffusion agents (as users and providers) by maximising the indirect benefits of innovation.

A preliminary conclusion could be to increase emphasis on innovation policy and to make a central place for it in IMS implementation. It seems also appropriate to support the development of industrial structures that exploit the systemic, generic and diffusion aspects of modern production systems, instead of favouring isolated innovations in specific high technology sectors (national or European ‘champions’).

With respect to SMEs, it could be necessary to setup a specific programme action to assure their effective involvement, for example, based on current Community R&D policies in favour of SMEs. Given the heterogeneity of SMEs and the diversity of their needs, it may be appropriate to link IMS implementation with regional networks involved with innovation policy and SMEs.
VI. Conclusions

By way of conclusion, the following series of salient points have been synthesised out of the above discussions:

- **An overall** strategy for IMS from a European perspective, has to be conceived with respect to four **principal** dimensions (see Figure 1):
  1. The overall framework defined by IMS-specific characteristics [i.e. a set of *issues* which drive the initiative (globalisation etc.); a set of *principles* which guide implementation (balanced co-operation, etc.); and a set of *selection criteria* (compliance with technical themes, etc.)] and the EU Policy context (FPV etc.).
  2. The general competitive position and prospects for manufacturing industry in Europe.
  3. The situation regarding relative technological strengths, weaknesses, opportunities and threats (SWOT) of manufacturing industry in Europe.
  4. Factors governing conditions for international co-operation and knowledge transfer & trading.

- The strategy discussions focused mainly on the questions of choosing the optimal thematic scope/coverage, and identifying the participant-types most likely to derive benefit from the scheme.

- The already primarily ‘soft technology’ frame of IMS should be upheld as the main reference basis against which to make a strategic narrowing of technological themes, by, for example, matching the frame against a select list of *key technologies*, be they individual ‘hard’ technologies, ‘soft’ technologies, or the integration of both.

- A clear distinction is made between a strategy which purports to attain greater added-value results through some degree of cross-project integration, as opposed to an independent project-by-project approach.

- The industries and technologies involved in projects should be clearly applicable to products and markets with good growth potential. Regarding the use of some firm taxonomy or typology as a means of identifying a preferred target group for the IMS scheme, the SWOT-based discussion was inconclusive and consequently for the time being, dismissive on this count. However, in relation to the ‘international co-operation’ dimension of IMS, so-called *scale-intensive* and *science-based* firms characterised by their use of complex and science-based technologies, the production of goods for the global market, and their dependence on network structures and greater number of links with external organisations, are the best prepared to benefit from a scheme like IMS. The question remains whether or not to make this part of the European strategy, or whether to couple this dimension with attempts to facilitate the participation of firms that stand to benefit, but naturally
might not be inclined to get involved (or should this latter best be left to other co-operation schemes?).

- Projects addressing truly global issues (standardisation, etc.) should involve partners from different regions who start from similar positions of weakness or strength regarding technology and competitiveness. To give this some substance, it would be important to take stock of the present priorities in the field of norms and standards within the various international bodies, as well as the views of manufacturing industry federations.

- If the strategy is to favour knowledge exchange and trading in a ‘catch-up’ mode, the projects should involve areas where the EU partners have clear critical strengths and clear critical weaknesses, each of which finds counter-balancing degrees of competence in the non-European partners.

- Finally, more categoric and specific statements on the current and emerging state of affairs for manufacturing industry in Europe, and derived options for a European IMS strategy, have not been possible because of a big information gap in pertinent areas. That is to say that there is a rather poor or very fragmented & dispersed empirical information base at EU level on some of the most policy relevant drivers of change in industry and the broader economy - in particular, the principal dimensions of the intangible economy (covering the ‘soft’ technology domain, and the knowledge infrastructure).

![Diagram](https://via.placeholder.com/150)

**Figure 1. Four dimensions from which to compose a European IMS strategy.**
References

ANNEX I

*European Industry ‘Competitiveness’ SWOT Overview*

by The Irish Productivity Centre

Introduction

1. EUROPEAN MANUFACTURING INDUSTRY - STRENGTHS AND WEAKNESSES
   1.1. Macro analysis perspective
       High, Medium and Low Technology Industry
       Value-added
       Employment and Productivity
       Export Performance
       Summary
   1.2. Further analysis on Demand structured basis
       Capital Goods
       Fast Moving Consumer Goods
       Staple Commodities
       Some Generic Manufacturing Themes
   1.3. Performance of S&T
   1.4. Conclusions

2. EUROPEAN MANUFACTURING INDUSTRY - THREATS AND OPPORTUNITIES
   2.1. Introduction
   2.2. Threats
   2.3. Opportunities
   2.4. Sector Specific Threats and Opportunities:

3. SUMMARY OF THE POSITION OF EUROPEAN MANUFACTURING INDUSTRY

References
**Introduction**

The changes undergone by manufacturing industry in the last two decades have been such as to make this sector of the economy almost unrecognisable. Changes in consumer demand, increased sophistication of the means of production and the restructuring of industry through a hollowing-out process have been the principal challenges met by manufacturers throughout the industrialised world. A significant feature of this transition has been the increasing acceptance by manufacturing companies of the necessity for research and development to respond to the challenges so as to retain and increase market share. However, until recently, the availability of R&D funds in these areas has been limited.

The Intelligent Manufacturing Systems (IMS) programme has grown out of efforts by leading international companies to test the benefits of collaborating in the face of the major challenges facing manufacturers while retaining or improving their respective market positions. This industry-led framework for international co-operation in R&D is supported by governments in the US, Canada, Australia and Japan and is being adopted by the European Union within the scope of its industrial research programmes.

As part of a consultation process to guide the development of a strategy for the implementation of IMS in Europe, the Institute for Prospective Technological Studies (IPTS) was requested to carry out a review of up-to-date literature on the situation of European Industry, in terms of its principal strengths and weaknesses in the context of the programme. The terms of reference of this phase of the study are set out in Annex III.

In a study of the scope undertaken here, it would not be feasible to provide a detailed picture of every industrial sector and the specific problems to be addressed in an IMS context. Instead a broader more generic view is taken of different categories of activity in manufacturing. In addition the focus of the examination is on strategic aspects of the situation in European manufacturing industry rather than on the more familiar and more widely analysed operational strengths and weaknesses.
1. EUROPEAN MANUFACTURING INDUSTRY - STRENGTHS AND WEAKNESSES

1.1. Macro analysis perspective

For the purposes of this exercise European manufacturing industry will be treated in aggregate for an initial sweep of analysis. Then it will be segmented according to its technology classification, using the OECD classification basis. Later a more demand oriented segmentation will be used.

To put European Manufacturing industry in perspective, Figure 1. shows its performance in comparison to that of the US and Japan in the last decade.

Figure 1. Employment and Value-Added (1990 prices) in EU, US and Japan 1985-96

From 1985 to 1992 both US and EU showed similar development in terms of both employment and value added. Since 1992 the US has had considerable growth in value added while the EU has stagnated and the US has maintained its manufacturing employment level while that of the EU has
continued to decline. Japan had good growth of value added up until 1991. Since then growth has been halted while manufacturing employment has slipped back from the earlier steady growth. Under the influence of increasing globalisation, individual companies have made decisions about locating manufacturing capacity in different regions of the world, so that the profile of manufacturing in each region is continuously changing. To gain some picture of the pattern of change the following Figures set out the movement of Manufacturing Foreign direct Investment for each of the members of the Economic Triad.

Figure 2. Foreign Direct Investment - Inward

![Graph showing Manufacturing Foreign Direct Investment - Inward](image-url)
Since 1983 the EU has been a significant net exporter of Foreign Direct Investment (FDI) in manufacturing, operating at a level of two to three times that of the US and many times that of Japan. In the peak years of investment, in 1989 and 1990, the EU invested heavily in the US, while attracting only about half the amount in inward investment from the US and Japan. The very low level of inward investment by Japan and the modest level of outward investment reflect the fact that Japan remains a largely closed market to outsiders. At the same time Japanese companies are highly selective in their manufacturing investments overseas. The large negative balance of investment for the EU obviously has contributed in some way to the stagnation of EU manufacturing output.

High, Medium and Low Technology Industry
This classification of manufacturing industry groups the sectors based on their R&D intensity, which is the ratio of R&D expenditure to production expenditure (OECD 1995,1996). The three categories are:
High-tech sectors: aerospace equipment manufacturing and repair, manufacture of pharmaceutical products, manufacture of office and data processing machinery, electrical engineering and instrument engineering;
Medium-tech sectors: Chemical industry, mechanical engineering industry, manufacture of motor vehicles and motor vehicle parts and accessories, processing of rubber and plastics, processing of non-ferrous metals, manufacture of other means of transport;
Low-tech sectors: mineral oil refining, manufacture of metal articles excluding vehicles and mechanical engineering, production and preliminary processing of metals, boat and ship building, repair and maintenance, food, drink and tobacco industry, textile industry, clothing and footwear, leather and leather goods industry, printing and publishing, manufacture of paper and paper products.
Using this classification, it is possible to isolate some additional features of manufacturing industry, which give a guide to the comparative strengths and weaknesses of manufacturing in Europe versus the US and Japan. The Table below indicates clearly the difference in importance within the overall manufacturing sector of the technology groupings in each of the regions.

### Table 1. Proportions of Total Manufacturing Value Added at current prices

<table>
<thead>
<tr>
<th></th>
<th>EU</th>
<th>USA</th>
<th>JAPAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH TECH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.0</td>
<td>20.4</td>
<td>0.4</td>
<td>24.2</td>
</tr>
<tr>
<td>MED. TECH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33.6</td>
<td>33.3</td>
<td>-0.3</td>
<td>31.0</td>
</tr>
<tr>
<td>LOW TECH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46.4</td>
<td>46.3</td>
<td>-0.1</td>
<td>44.8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Source: OECD

**Value-added**

The importance of the high-tech sectors in the EU has not changed much in the decade from 1985 to 1994. By contrast, in the US this group of sectors have remained significantly more important in the economy of the region. In Japan the high-tech sectors had an importance equal to that in Europe in 1985 but Japan had increased the level of importance by almost 10% by 1994.
Medium-tech and low-tech sectors are of more importance to the EU and clearly the EU retains considerable strength in these areas. If the automotive sector is taken as an example of a medium-tech sector, Europe has a strong presence in world markets. The principal strength of the European industry lies in its design and innovation. However, considerable improvements are needed to allow the industry to shorten development cycles without compromising the excellence of the designs. The requirements of customers for more customisation in the specification of the product demands from the manufacturers more modularization in design and an extension of the concept of building many product offerings based on the same design platform. An increase would be expected in this area in alliances between manufacturers formed for the purposes of particular types of product development. Niche market requirements at the interface between passenger cars and commercial vehicles are a good example of this (e.g. people carriers).

Research and development in the sector is being concentrated on improving efficiency of power units, improving safety and environmental impact and the use of new and advanced materials. The industry in the EU has established technological strengths in many of the development areas but will need to at least maintain its efforts to combat competition from Japan and the US. In the context of the IMS programme, any European strategy should ensure that these areas are not neglected.

**Employment and Productivity**

In terms of employment and investment high-tech sectors involve a smaller proportion of total manufacturing than in the case of value added. This reflects the fact that these sectors have higher productivity levels and are less tangible investment intensive than either the medium-tech or low-tech sectors. In the US the proportion of manufacturing employment in high-tech sectors has fallen by almost 20% in the decade to 1994 while in the EU it has risen by 2%. Since output in both regions grew by 2% clearly the US has improved its productivity in these sectors over the EU by a large margin. This is a further indication of a weakness in the high-tech areas. The differentials between the US and the EU in terms of productivity in the medium-tech and low-tech sectors are much smaller and show near parity of performance in medium-tech and a positive performance for the EU in the low-tech sectors.

**Export Performance**

The concern that is most often expressed about the relative weakness of Europe in the high-tech sector centres on the expanding export performance of these sectors and the degree to which their
comparative advantage lies in innovative products and services and not on low cost (Competitiveness Advisory Group, 1996). High-tech sectors are more open to competition and are more export oriented. In the US high-tech sectors account for 38% of manufacturing exports against 24% in Europe. Over the past decade these proportions have been expanding. In Japan the proportion is 25% even though Japan has no significant aerospace industry which is the largest source of high-tech exports for both the US and EU (VOLIMEX-Trade in Manufacturing).

The changing pattern of trade, particularly in high-tech products, gives useful indications of the relative strengths and weaknesses of the members of the TRIAD. With the emergence of newly industrialized economies, the shares of both imports and exports in this important area of activity held by the US, Japan and EU will be reduced. However, it is the relative rate of decline, which indicates who is leading or lagging. Tables 2 and 3 below show the absolute levels of activity and the changes from 1990 to 1995, while Tables 4 and 5 show the same information in terms of shares of total world activity.

**Table 2. Imports of High-tech Products (millions ECU)**

<table>
<thead>
<tr>
<th></th>
<th>From EU15</th>
<th>US</th>
<th>Japan</th>
<th>Others</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By EU15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU15</td>
<td>31491</td>
<td>14863</td>
<td>25974</td>
<td>72333</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td>11903</td>
<td>19583</td>
<td>26595</td>
<td>58081</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>2677</td>
<td>10945</td>
<td>3169</td>
<td>16791</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>13435</td>
<td>25350</td>
<td>11679</td>
<td>62517</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>28015</td>
<td>67786</td>
<td>46130</td>
<td>209722</td>
<td></td>
</tr>
<tr>
<td>1995i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From EU15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU15</td>
<td>39208</td>
<td>17489</td>
<td>45815</td>
<td>102512</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td>17988</td>
<td>31375</td>
<td>68581</td>
<td>117944</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>6096</td>
<td>16936</td>
<td>14964</td>
<td>37996</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>34945</td>
<td>58637</td>
<td>35801</td>
<td>190608</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>59029</td>
<td>114781</td>
<td>84665</td>
<td>449060</td>
<td></td>
</tr>
</tbody>
</table>
Table 3. Exports of High-tech. Products (millions ECU)

<table>
<thead>
<tr>
<th>1990e</th>
<th>To EU15</th>
<th>US</th>
<th>Japan</th>
<th>Others</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By EU15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US</td>
<td>27589</td>
<td>8977</td>
<td>36087</td>
<td>72653</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>14298</td>
<td>19982</td>
<td>18107</td>
<td>52387</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>11840</td>
<td>19033</td>
<td>12991</td>
<td>46907</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>53727</td>
<td>53152</td>
<td>14438</td>
<td>224240</td>
<td></td>
</tr>
<tr>
<td>1995e</td>
<td>To EU15</td>
<td>US</td>
<td>Japan</td>
<td>Others</td>
<td>World</td>
</tr>
<tr>
<td>-------</td>
<td>---------</td>
<td>------</td>
<td>-------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US</td>
<td>29028</td>
<td>11638</td>
<td>59509</td>
<td>100175</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>17234</td>
<td>29278</td>
<td>39061</td>
<td>85573</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>28829</td>
<td>38611</td>
<td>68114</td>
<td>147374</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>75091</td>
<td>88126</td>
<td>22957</td>
<td>421233</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Imports Shares of High-tech Prods. (millions ECU)

<table>
<thead>
<tr>
<th>1990i</th>
<th>From EU15</th>
<th>US</th>
<th>Japan</th>
<th>Others</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By EU15</td>
<td>-</td>
<td>15.02</td>
<td>7.09</td>
<td>12.38</td>
<td>34.49</td>
</tr>
<tr>
<td>US</td>
<td>5.68</td>
<td>-</td>
<td>9.34</td>
<td>12.68</td>
<td>27.69</td>
</tr>
<tr>
<td>Japan</td>
<td>1.28</td>
<td>5.22</td>
<td>-</td>
<td>1.51</td>
<td>8.01</td>
</tr>
<tr>
<td>Others</td>
<td>6.41</td>
<td>5.57</td>
<td>5.75</td>
<td>5.75</td>
<td>29.81</td>
</tr>
<tr>
<td>Total</td>
<td>13.36</td>
<td>32.32</td>
<td>22.00</td>
<td>32.32</td>
<td>100.00</td>
</tr>
<tr>
<td>1995i</td>
<td>From EU15</td>
<td>US</td>
<td>Japan</td>
<td>Others</td>
<td>World</td>
</tr>
<tr>
<td>-------</td>
<td>-----------</td>
<td>------</td>
<td>-------</td>
<td>--------</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By EU15</td>
<td>-</td>
<td>8.73</td>
<td>3.89</td>
<td>10.20</td>
<td>22.83</td>
</tr>
<tr>
<td>US</td>
<td>4.01</td>
<td>-</td>
<td>6.99</td>
<td>15.27</td>
<td>26.26</td>
</tr>
<tr>
<td>Japan</td>
<td>1.36</td>
<td>3.77</td>
<td>-</td>
<td>3.33</td>
<td>8.46</td>
</tr>
<tr>
<td>Others</td>
<td>7.78</td>
<td>13.06</td>
<td>7.97</td>
<td>13.63</td>
<td>42.45</td>
</tr>
<tr>
<td>Total</td>
<td>13.15</td>
<td>25.56</td>
<td>18.85</td>
<td>42.44</td>
<td>100.00</td>
</tr>
</tbody>
</table>
Table 5. Export Shares of High–tech Prods. (millions ECU)

<table>
<thead>
<tr>
<th></th>
<th>1990e</th>
<th>1995e</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To EU15</td>
<td>US</td>
</tr>
<tr>
<td>By EU15</td>
<td>-</td>
<td>6.30</td>
</tr>
<tr>
<td>US</td>
<td>12.30</td>
<td>-</td>
</tr>
<tr>
<td>Japan</td>
<td>6.38</td>
<td>8.91</td>
</tr>
<tr>
<td>Others</td>
<td>5.28</td>
<td>8.49</td>
</tr>
<tr>
<td>Total</td>
<td>23.96</td>
<td>23.70</td>
</tr>
</tbody>
</table>

Source: UN Trade statistics

The penetration of the Japanese market for these products by the EU lags behind US and the penetration of the US market by Europe lags behind Japan. The European share in Japan has grown while its share in the US has fallen faster than the fall in Japan’s share.

The US and Europe have roughly equal proportions of manufacturing exports in medium-tech sectors, approx. 40%. In low-tech sectors Europe has a greater share of its exports concentrated than the US, 36% as against 22%.
Table 6. Percentage of Total Manufacturing Exports for major sectors (1995).

<table>
<thead>
<tr>
<th></th>
<th>EU</th>
<th>Specialisation</th>
<th>Japan</th>
<th>Specialisation</th>
<th>US</th>
<th>Specialisation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Export share</td>
<td></td>
<td>Export share</td>
<td></td>
<td>Export share</td>
<td></td>
</tr>
<tr>
<td>Food, Drink, Tobacco</td>
<td>8.57</td>
<td>115.91</td>
<td>0.50</td>
<td>6.77</td>
<td>7.29</td>
<td>98.72</td>
</tr>
<tr>
<td>Textiles, Clothing</td>
<td>7.71</td>
<td>125.01</td>
<td>1.76</td>
<td>28.48</td>
<td>3.61</td>
<td>58.58</td>
</tr>
<tr>
<td>Leather, Footwear</td>
<td>2.13</td>
<td>118.71</td>
<td>0.13</td>
<td>7.18</td>
<td>1.61</td>
<td>89.65</td>
</tr>
<tr>
<td>Wood Prods, Furniture</td>
<td>3.89</td>
<td>112.16</td>
<td>0.66</td>
<td>19.10</td>
<td>3.61</td>
<td>104.10</td>
</tr>
<tr>
<td>Chemical Prods, Publ,Printing</td>
<td>20.45</td>
<td>110.85</td>
<td>10.33</td>
<td>56.00</td>
<td>16.40</td>
<td>88.85</td>
</tr>
<tr>
<td>Non-Metallic, Mineral Prods</td>
<td>2.18</td>
<td>121.83</td>
<td>1.16</td>
<td>64.93</td>
<td>0.89</td>
<td>49.47</td>
</tr>
<tr>
<td>Basic Metal Prods</td>
<td>5.42</td>
<td>116.78</td>
<td>4.57</td>
<td>98.47</td>
<td>2.22</td>
<td>47.80</td>
</tr>
<tr>
<td>Non Elec. Equipment</td>
<td>14.04</td>
<td>88.11</td>
<td>21.05</td>
<td>132.07</td>
<td>19.24</td>
<td>120.70</td>
</tr>
<tr>
<td>Office &amp; Data Proc. Mach.</td>
<td>3.36</td>
<td>72.73</td>
<td>7.59</td>
<td>164.01</td>
<td>7.05</td>
<td>152.52</td>
</tr>
<tr>
<td>Electrical Equipment</td>
<td>9.92</td>
<td>78.27</td>
<td>23.72</td>
<td>187.19</td>
<td>15.57</td>
<td>122.85</td>
</tr>
<tr>
<td>Metal Prods.</td>
<td>4.01</td>
<td>111.45</td>
<td>2.49</td>
<td>69.23</td>
<td>2.88</td>
<td>80.01</td>
</tr>
<tr>
<td>Transport Equipment</td>
<td>16.24</td>
<td>88.82</td>
<td>26.54</td>
<td>145.10</td>
<td>20.41</td>
<td>111.61</td>
</tr>
<tr>
<td>Motor Vehicles &amp; parts</td>
<td>12.47</td>
<td>93.78</td>
<td>21.61</td>
<td>162.53</td>
<td>11.54</td>
<td>86.80</td>
</tr>
<tr>
<td>Aerospace.</td>
<td>2.44</td>
<td>71.45</td>
<td>0.23</td>
<td>6.81</td>
<td>8.16</td>
<td>239.15</td>
</tr>
</tbody>
</table>
It can be observed that the sectors in which the EU has the highest export specialization are Mechanical engineering, Metal Products, Textiles, Clothing, Leather and Footwear, Food, Drink and Tobacco, Wood and Furniture and Chemicals. The US and Japan have their highest export specialization in Electrical engineering, Office and Data Processing machinery, Instrument Engineering and Transport equipment. The contrast between the sectors centres on the relative weights in relation to value-added and employment. The EU sectors are more employment intensive and contribute relatively less value-added than the US and Japanese sectors.

**Summary**

The picture emerging from this general overview analysis depicts EU industry as struggling to maintain its position relative to the main competitive blocs. It is losing some ground in the high-tech areas but retains a significant position in world markets none the less. In medium-tech sectors it still has a strong concentration and has maintained its hold on markets and production capability. The low-tech sectors remain strong elements of the EU manufacturing scene and will remain very important in relation to intra-EU trade. While some of these areas are vulnerable to competition from newly emerging low-cost economies, there is scope for continuously improving many of these sectors and they should not be neglected in any IMS strategy.
1.2. Further analysis on Demand structured basis

To give a broader perspective on the state of European industry in the context of the IMS concepts, it would be appropriate to look at the particular issues which affect groups of firms clustered according to the types of demand patterns which they meet, and reflect on the implications of those issues. For the purpose of this analysis we have chosen three areas: capital goods, fast-moving consumer goods, and staple commodities.

**Capital Goods**

Capital goods manufacturing involve large scale operations with significant levels of sub-contracting. Modern developments include highly developed networking between customers, main contractors and suppliers/sub-contractors. The processes of integration of design, production, installation, commissioning, and reconfiguring together with finally recycling of outdated systems will dominate this area of activity in the future. Development priorities for companies and consortia wishing to succeed in the supply of capital goods will focus on many mainstream issues under the IMS umbrella. Reduction in design time and the adoption of methodologies for validation of performance at design stage are two key aspects of this activity. Both Europe and the US have been slower to progress on these issues than Japan and traditional strengths in capital goods manufacturing have been eroded.

Studies of the Machine tool industry in the early 1990s exposed several weaknesses in the area of responsiveness to design changes and in development lead times in both the European and US industries. Nevertheless, the need for increased sophistication in the configuration of fabrication operations in industry generally has opened up opportunities for companies, with the depth of engineering skill traditional in Europe, who can master the logistics and co-ordination needed to meet this form of demand. The US has been improving its position through alliances and co-operation with Japanese companies. Europe still lags somewhat in this area.

Europe has considerable strength to offer in another critical area of capital goods supply, that of environmental compliance. Many of the European standards for environmental management dictate the design standards for equipment and plant and are sufficiently advanced to give European manufacturers an advantage. By combining this with the newer management practices and technologies, capital goods manufacture can be a major contributor to a strengthened manufacturing sector. Within the IMS programme capital goods manufacturing should provide a fruitful field of application.
Fast Moving Consumer Goods

Fast moving consumer goods (FMCG) present a very different set of problems for Europe. The 1970s and 80s assault by Japan on many of these markets almost eliminated European and US companies from participation. The quality revolution on which it was founded has resulted in a situation where quality is now a basic non-negotiable criterion in all countries. The challenge has been extended in that newly emerging Asian economies have targeted these product areas, particularly in electronic and electrical goods and leisure goods. In these areas, Europe has only limited presence and has had to resort to more specialised and premium niches of the markets. In many of these niches the keys to success are style design and branding. For the future however, it is likely that attributes such as multi-functions and sophisticated programmability will be critical features. To support such developments Europe’s high-tech capabilities must be retained and enhanced.

Another area in which Europe is strong within FMCG is in sophisticated food processing and packaging. This is an area of activity which is not subject to a great deal of external competition as regulation and distribution issues tend to force the location of production near the market. This is also one of the areas where the integration of the product development, production and distribution demands innovative management and the use of information and communication technologies in the organisation of the complete supply chain. In time the operating systems of production and distribution of FMCG will be triggered directly from the point of sale outlets in response to customer preferences. The development of such systems provides considerable opportunities for countries and regions with advanced technological capabilities over a wide range of industrial and commercial activities. Europe has the basic capacity to meet these demands but its adoption of innovation in these areas has been traditionally cautious.

Staple Commodities

The third category of demand pattern, which we would like to consider, is that of staple commodities such as basic foodstuffs, oil and petroleum production, paper and plastics, basic metals etc. In many cases, production of these commodities is for local consumption with heavy transportation costs offering protection against low-cost imports. These activities are normally very capital intensive and embody significant economies of scale. However, even in these areas, modern technological developments are lowering the barriers to entry for manufacturers and the scale of viable plants is being reduced. Improvements in process control are allowing increased product differentiation and offering wider choice in the marketplace. The development of this product versatility is a further source of opportunity to advanced economies to maintain their share of these segmenting markets. European industry has considerable experience and accumulated knowledge in many of these areas
which leaves it well placed as a region for innovation in this category of production. The region’s weakness, in some cases, derives from its lack of internal sources of raw materials. Over-capacity internationally is also a threat in the basic commodity markets, but this can be counteracted by process innovation and differentiation.

Europe has a long established capacity in many of these areas of activity, which takes time and a high level of investment to restructure. Many of these industries are going through re-organisation and restructuring at present and are having difficulty adjusting to the new market situations. There are dangers in this process in terms of the loss of tacit knowledge and critical industrial know-how. It will be much more problematic for such firms to adopt new concepts and philosophies of operation if their technological knowledge base has been seriously eroded.

As an example of a sector in this area the following Table 7 outlines the principal issues facing the steel sector and compares the situation in the three main trading blocs.

Table 7. Main issues of steel sector in the triad

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Europe</th>
<th>Japan</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inputs</strong></td>
<td>High cost of energy (electricity)</td>
<td>High cost of energy (electricity)</td>
<td>Low cost of energy (electricity)</td>
</tr>
<tr>
<td></td>
<td>Moderate cost of scrap</td>
<td>Moderate cost of scrap/ low availability</td>
<td>Low cost of scrap/ high availability</td>
</tr>
<tr>
<td></td>
<td>Low cost of capital from banks</td>
<td>Low cost of capital from banks and unrealised gains</td>
<td>High cost of capital</td>
</tr>
<tr>
<td></td>
<td>Less pressure to perform</td>
<td>Integrated producers face more constraints</td>
<td>High hurdle rates/ short payback requirements</td>
</tr>
<tr>
<td></td>
<td>No venture capital</td>
<td>Integrated producers face more constraints</td>
<td>High hurdle rates/ short payback requirements</td>
</tr>
<tr>
<td><strong>Labour</strong></td>
<td>Relatively inflexible labour force</td>
<td>Flexible workforce through subcontracting</td>
<td>Minimills non-unionised</td>
</tr>
<tr>
<td></td>
<td>Strict legal constraints</td>
<td>Lifetime employment</td>
<td></td>
</tr>
<tr>
<td><strong>Other Issues</strong></td>
<td>Strained /regulated</td>
<td>Co-operative</td>
<td>Adversarial in integrated production units</td>
</tr>
<tr>
<td></td>
<td>Resistance to change</td>
<td>Some Flexibility; able to change</td>
<td>Integrated mills resistant to change; opportunities for minimills</td>
</tr>
</tbody>
</table>

Source: Mc Kinsey Global Institute
The outlook for the steel industry has to be seen from the standpoint of two different groups on the production side. Production will continue to shift from integrated mills to mini-mills or, at least, to less complex configurations of integrated facilities. This will occur for reasons of high productivity, better returns on capital investment and lower impact on the environment. New technological advances allow the mini-mills to compete in previously excluded areas such as flat products. The consequent reduction in the minimum scale of such mills to well below the 1 million tons level has opened up the competition for all areas of the industry.

Integrated producers will have to respond by reorganising or closing. Reduction in complexity will be a major element in regaining competitiveness. One strategy being considered by many players in the integrated segment is the abandonment of primary iron making and purchasing semi-finished steel to make final products. Such a strategy could be very viable in Europe with the availability of cheap blast furnace iron from former communist countries. However the employment reduction in the restructured companies would be high.

Specialisation in product performance and capability is one of Europe’s potential advantages in steel making.

This example can be repeated for other commodity sectors with similar responses needed in terms of flexibility and innovation.

**Some Generic Manufacturing Themes**

Within the scope of IMS programmes there are a number of areas of manufacturing technology which have wide cross-sectoral application and which are the focus of much attention in every country.

The following areas have been identified by manufacturers in the US as areas of concern with the US losing ground in global terms:

- Robotic and automated equipment,
- Flexible manufacturing,
- High-speed machining,
- Precision machining and forming
- New Materials and applications

Japanese technology is considered to be the most advanced in these areas and the situation of Europe would be rated as no better than, and maybe a little behind, that in the US. These will be critical technologies for the future of many industries. The area of rapid product development will also be a key focus of the IMS initiative. A recent study of the relative strengths of the US, Europe and Japan carried out by the US based Japanese Technology Evaluation Committee (JTEC) in Rapid Prototyping Technology summarised its findings in the following Table 8 (Holdridge, 1995).
Table 8. Relative strengths in Rapid Prototyping Technology in the triad.

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>United States</th>
<th>Europe</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process innovation</td>
<td>XXX</td>
<td>XX</td>
<td>X</td>
</tr>
<tr>
<td>Process development</td>
<td>XX</td>
<td>XX</td>
<td>X</td>
</tr>
<tr>
<td>Machine design</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CAD &amp; interfaces</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastics</td>
<td>XX</td>
<td>X</td>
<td>X☆</td>
</tr>
<tr>
<td>Metals</td>
<td>X☆</td>
<td>X☆</td>
<td></td>
</tr>
<tr>
<td>Ceramics</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>APPLICATIONS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal casting</td>
<td>XXX</td>
<td>X☆</td>
<td>X</td>
</tr>
<tr>
<td>Tooling</td>
<td>XXX</td>
<td>XX☆</td>
<td>X☆</td>
</tr>
<tr>
<td>Medical</td>
<td>X</td>
<td>XXX</td>
<td>XX</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INFRASTRUCTURE</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>XX</td>
<td>XX</td>
<td>X☆</td>
</tr>
<tr>
<td>Government support for R&amp;D</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Industry support for R&amp;D</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Key**

- **Xs** = relative strength; more Xs = more strength
- **☆** = new developments and initiatives pointing to strength in the future

source: JTEC study (Holdridge, 1995).

The picture depicted by this study is encouraging for Europe although the study concentrated its analysis on the situation in Germany and France, where the main European capability is centred.

**1.3. Performance of S&T**

In terms of patents granted in the different sectors, Table 9 shows the performance of the Triad in 1995.
Table 9. Patents granted in different sectors in the triad

<table>
<thead>
<tr>
<th>Sector</th>
<th>Percentage of European Patents granted in 1995 by Sector</th>
<th>Index of Specialisation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EU</td>
<td>US</td>
</tr>
<tr>
<td>Aerospace</td>
<td>42.9</td>
<td>45.8</td>
</tr>
<tr>
<td>Comp.&amp;Off.Mach.</td>
<td>22.2</td>
<td>48.5</td>
</tr>
<tr>
<td>Electronics</td>
<td>35.3</td>
<td>38.2</td>
</tr>
<tr>
<td>Instruments</td>
<td>35.9</td>
<td>44.3</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>35.7</td>
<td>45.5</td>
</tr>
<tr>
<td>Chemicals</td>
<td>41.9</td>
<td>38.2</td>
</tr>
<tr>
<td>Electrical Mach.</td>
<td>46.3</td>
<td>30.0</td>
</tr>
<tr>
<td>Motor Vehicles</td>
<td>60.9</td>
<td>22.0</td>
</tr>
<tr>
<td>Total Sectors</td>
<td>43.6</td>
<td>35.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage of US Patents granted in 1995 by Sector</th>
<th>Index of Specialisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sector</td>
<td>EU</td>
</tr>
<tr>
<td>Aerospace</td>
<td>23.0</td>
</tr>
<tr>
<td>Comp.&amp;Off.Mach.</td>
<td>8.1</td>
</tr>
<tr>
<td>Electronics</td>
<td>11.2</td>
</tr>
<tr>
<td>Instruments</td>
<td>12.5</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>22.4</td>
</tr>
<tr>
<td>Chemicals</td>
<td>25.2</td>
</tr>
<tr>
<td>Electrical Mach.</td>
<td>14.8</td>
</tr>
<tr>
<td>Motor Vehicles</td>
<td>19.9</td>
</tr>
<tr>
<td>Total Sectors</td>
<td>15.9</td>
</tr>
</tbody>
</table>

Source: Second European Report on S&T Indicators.

The Index of Specialisation shows the ratio of the sectoral percentage to the all sectors percentage.
This Table shows that the EU lags its competitors in patenting in the US, while in Europe the US is particularly aggressive with almost 36% of European patents granted. In sectors, the EU demonstrates particular strengths in US patenting in Chemicals, Pharmaceuticals, Aerospace and Motor Vehicles. Its main weakness is in Computers and Electronics. Japan, on the other hand, is very strong in Electronics and Computers, as well as Electrical Machinery.

In the area of scientific publication, the EU runs the US a close second with Japan well behind. Within the specific fields of science, the EU has the highest level in Chemistry and Physics, outperforming the US. However, when the index of specialisation is considered, which compares the individual field percentages with the overall percentage, the EU displays a remarkable level of consistency over the various fields with Clinical Medicine and Biomedical research at the top of its range. The US scores rather lowly in Chemistry and Physics, while Japan is very low in Mathematics and Clinical Medicine. Japan displays relative strength in Chemistry, Physics and Engineering. The US is strongest in Earth and Space science.

Table 10. Scientific publications and specialisation index in the triad

<table>
<thead>
<tr>
<th></th>
<th>Percentage of Scientific Publications by Scientific field 1995</th>
<th>Index of Specialisation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EU</td>
<td>US</td>
</tr>
<tr>
<td>Clinical Medicine</td>
<td>37.6</td>
<td>43.2</td>
</tr>
<tr>
<td>Biomedical Research</td>
<td>39.5</td>
<td>43.1</td>
</tr>
<tr>
<td>Biology</td>
<td>35.3</td>
<td>42.1</td>
</tr>
<tr>
<td>Chemistry</td>
<td>34.6</td>
<td>27.9</td>
</tr>
<tr>
<td>Physics</td>
<td>36.3</td>
<td>33.9</td>
</tr>
<tr>
<td>Mathematics</td>
<td>38.2</td>
<td>42.2</td>
</tr>
<tr>
<td>Engineering</td>
<td>33.8</td>
<td>41.8</td>
</tr>
<tr>
<td>Earth and Space Science</td>
<td>31.5</td>
<td>50.6</td>
</tr>
<tr>
<td>All Categories</td>
<td>36.2</td>
<td>39.5</td>
</tr>
</tbody>
</table>

Source: Second European Report on S&T Indicators.
The main indication from this data is that the EU has no fundamental weakness in its current S&T capability. However, some concern is expressed about the future in terms of a fall off in the study of science subjects at second level education.

1.4. Conclusions

Overall the situation in European manufacturing industry presents a mixed picture. In high-technology sectors, Europe has a range of potential opportunities but its performance to date in keeping abreast of the US and Japan has been weak. Europe has not entered the same level of strategic alliances with Japanese or US companies as the other two groups have with each other.

The technological base in Europe, founded on high quality basic research, remains strong but a shortfall in investment is preventing the gaps, particularly with Japan, being closed. However, not all of the difficulties faced by Europe are can be resolved with additional investment in R&D. Much of the lack of strength in European manufacturing lies in the failure to adopt new techniques and technologies with an attention to detail at the implementation stage, which ensures that new principles and concepts are tailored to the precise conditions applying.

The main strengths of manufacturing industry in Europe are in medium-technology sectors rather than in high-technology sectors. Europe’s competitive capability would be improved by focusing on developing its position in the high-tech sectors as these are the growth areas. In particular, more SMEs need to be involved in the high-tech sectors to bring Europe in line with the US and Japan.

The IMS programme would appear to be an ideal vehicle for European manufacturers as one of the requirements for strengthening capability is more collaboration with Japan and the US in developing concepts and technologies which continue to confer competitive advantage on developed economies.
2. EUROPEAN MANUFACTURING INDUSTRY – THREATS AND OPPORTUNITIES

2.1. Introduction

Much of manufacturing industry in Europe has followed different paths of development to those pursued in the US. A characteristic of major European companies has been their apparent understanding of the importance of manufacturing to economic strength. This has been particularly evident in Germany. Much of the decline in importance of manufacturing in the US in the late 1960s and 1970s can be traced to the evolution of corporate strategies in major companies. Monks quotes, as a typical example of this, the failure of RCA to invest $200 million needed to beat the Japanese in the race to develop the VCR while at the same time investing $1200 million to purchase a financial services company, the performance of which remained lack-lustre. It was not until the late 1980s that these strategies were reversed and the US government actively supported the renaissance of manufacturing.

The thread which runs through much of the recovery in US manufacturing is the focus on the exploitation of the results of S&T developments and in particular the incorporation of ICT developments into all facets of product and process technology. Developments for the future will need to be in tune with many emerging influences on customer behaviour and preferences. These influences can be discerned from the many foresight studies that have been carried out in various countries. These emerging influences and the technological discoveries and developments which arise, either because of them or as a response to them are expected to alter significantly the international patterns of trade and production.

The key factor will be the total management of knowledge resources and the co-ordinated integration of as many phases of the value chain as possible. The successful manufacturing company of the future will play the central role in organizing and directing the flows of value by controlling the critical elements of the operations which translate customer needs and desires into products and services and the associated flows of input resources needed to deliver them.

The transition involved poses many threats for existing industry and offers extensive opportunity for those companies that meet the challenge successfully.
2.2. Threats

Threats exist on two levels. The traditional threats to markets supplied by European manufacturers have been:

(a) the development of superior products by other developed economies,
(b) competition from low cost producers of comparable products.

These threats remain but will change in nature. In the meantime a further range of threats will emerge from within the existing structure of manufacturing industry.

Development of superior products:
The shift from mass-produced rigidly standardized products, which began in the 1950s, has reached a point where a level of customization, based on the supply of limited optional features, is available to customers. The future will see the continuation of this shift beyond the capability of existing mass production equipment and technologies to cope with demands. The threat lies in failure to sustain research programmes into the development of new products and processes to replace existing systems of production. One of the serious difficulties in this area is the problem of time horizons. The development time for the solutions to problems in this area is likely to be much longer than the normal investment time horizon of companies in Europe who rely on contemporary financial markets for investment. As a result, such development programmes may fail to gain support in internal competition for resources. In this regard European companies can be at disadvantage against Japanese companies.

The second threat in this area stems from the well-recognized problems which European industry appears to have in translating excellent basic research into marketable products and processes. Some of this problem can be traced to a lack of attention to detail in the development process and the subsequent implementation process within organizations. It is a failure in the type of integration, which is an essential component of custom manufacturing systems.

Competition from low cost producers:
This threat has tended to become less of a problem as the proportion of labour cost has been reduced in many sectors. However, it remains a potent threat in many commodity product areas. The practice of outsourcing to take advantage of low labour cost has attractive short term benefits for companies, but the hollowing of industry, as occurred with the US in the 1970s, is, in itself, a lesson worthy of heeding. The threat may be greatest from those countries, which are close to the main markets and
therefore can offer sophisticated just-in-time performance in addition to the low labour cost advantage.

Other major Threats:
Reference was made in the introduction to the importance of business strategy decisions to the maintenance of a strong capability in manufacturing. Short term responses to maximization of profit performance in response to financial market pressures has led many companies to downsize with a consequent loss of knowledge capital which has subsequently hampered development. Achieving the best balance of flexible automated operations calls for significant education and training for people to complement the advanced equipment and complex systems. The threat which may exist is inadequate investment in training and education which cannot be corrected quickly if skill levels are allowed to decline.

In the same vein, lack of research capability may result from any diminution of the role of sciences in the education systems of member countries. A worrying tendency has been seen in some countries of a lessening of popularity of basic science among second level students. By contrast some of the emerging and developing economies will have large numbers of highly qualified (and low cost) scientists and researchers capable of attracting research investment.

Another major area of threat comes from the slow adoption of new forms of work organization. While a number of European countries and companies have been pioneers in organizational innovation there remains a rigidity within both the labour markets and the traditional organizational structures in many sectors which will militate against successful exploitation of new technological developments.

2.3. Opportunities

For most sectors of manufacturing opportunities are developing from the economic advancement of a number of regions. The main Triad countries have growing economies with advances in the sophistication of customer demands fuelling the development of new products. These in turn are increasing the need for new processes and other forms of innovation.

Emerging regions in Asia and South America are experiencing growth and, while they are also posing threats as competitors, they are offering new markets for European products.
Liberalization of trade is also opening up markets, although there is some concern that the strength of
developed country producers may eventually lead to the re-introduction of protection for third world
producers of what might be called culture-specific products.
The main source of opportunity for European industry will be the same as for the US and Japan (and
other developed economies such as Canada and Australia). It will come from the incorporation of
knowledge value-added into products.
The principal opportunity that exists for all sectors and companies will stem from developing an
understanding of how new technologies impact on society. This requires the establishment of a new
Theory of Business to explain how and where value is created. Such a theory would have three
elements:
• a theory of value: explaining what is valuable to the customer to the extent that he/she is willing
to pay for it—either in money, effort or some other exchangeable utility. To understand how
technology is creating value there must be a model of the Value Mechanism.
• a theory of capabilities, processes and costs: explaining what are the processes that create the
value and/or make value creation cheaper than before? This requires a model about the Utility
Mechanism.
• a theory of functions, applications and skills: outlining what skills are necessary to run the value-
creating processes.

One arm of the strategy for IMS in Europe might be to tackle this problem.

2.4. Sector Specific Threats and Opportunities

There have been many studies and commentaries in individual countries and the EU Commission
focusing on the threats to and opportunities for various sectors and groupings within manufacturing
industry. The following Table gives a synopsis of the common threads that are found in such studies.
<table>
<thead>
<tr>
<th>Sector</th>
<th>Threat</th>
<th>Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerospace</td>
<td>Reduced Defence Spending</td>
<td>Aging Fleet Replacement</td>
</tr>
<tr>
<td></td>
<td>Rising Costs of R&amp;D</td>
<td>Advanced technology</td>
</tr>
<tr>
<td></td>
<td>Global Over-capacity</td>
<td>New materials and Processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical</td>
<td>Continuing Strength of Japan</td>
<td>R&amp;D Co-operation</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td>Products for environment, security and energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>conservation</td>
</tr>
<tr>
<td>Office and</td>
<td>Dominance of Japan and US in</td>
<td>Software development</td>
</tr>
<tr>
<td>Data</td>
<td>technology</td>
<td></td>
</tr>
<tr>
<td>Processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>Environmental Legislation</td>
<td>Growth Markets</td>
</tr>
<tr>
<td>Pharmaceuticals</td>
<td>Depletion of Science Base</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rising energy Costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rising Research Costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased International</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Competition</td>
<td></td>
</tr>
</tbody>
</table>

**Table 11. Sectoral Threats and Opportunities (contd.)**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Threat</th>
<th>Opportunity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Engineering</td>
<td>Import penetration from East Europe and Asia</td>
<td>Environmental challenges to engineering technology</td>
</tr>
<tr>
<td></td>
<td>Infringement of IPR on design</td>
<td>Development of sub-contract for international markets</td>
</tr>
<tr>
<td>Motor Vehicles and Parts</td>
<td>Environmental legislation</td>
<td>Exploitation of Design Capability Advanced Vehicle Technology Recycling of Materials</td>
</tr>
<tr>
<td></td>
<td>Strong Competition from NICs</td>
<td></td>
</tr>
<tr>
<td>Food and Drink</td>
<td>Health Issues</td>
<td>Growth Markets for Food and Spirits Reform of CAP</td>
</tr>
<tr>
<td></td>
<td>Over regulation</td>
<td></td>
</tr>
<tr>
<td>Industry</td>
<td>Threats</td>
<td>Opportunities of New Technical Uses of Textiles</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------------------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>Textiles, Clothing, Leather and Footwear</td>
<td>Low cost commodity imports, Theft of IPR</td>
<td>Fashion Goods for New Markets, Just in Time Delivery</td>
</tr>
<tr>
<td>Printing and Publishing</td>
<td>Reduction in Packaging, Restrictions on Direct Mail Advertising, Rising Energy Costs</td>
<td>Just in Time Delivery, Exploitation of ICT</td>
</tr>
</tbody>
</table>

The response to these threats and opportunities by European manufacturing Industry will determine whether it regains some of the losses it has sustained relative to its main trading competitors. A common thread running through the opportunities is the need for intelligent technological solutions which are accompanied by coherent strategies and operated by skilled, capable workforces. There are no cases on record of companies building sustainable competitive advantage on the best technology alone. Without the integration of people and technology in the factory the sought after improvements in productivity and performance are doomed to fail.

To illustrate the point, J.F Coates, a noted exponent of technology foresight, set out the following example of how this integration would work in practice (Figure 4).
Figure 4. How People and Technology Work Together in Manufacturing

Information Technology  The Manufacturing System  People

Networks  CAD/CAM  Virtual Reality  
Automated Materials Handling  Manufacturing Resources Planning  
Automation Robotics  Mechatronics  
Barcodes  Taggants  Global Positioning Systems  
Automated modular Re-manufacturing  
Self-diagnosis  (and repair)  Expert Systems  Online Assistance  

DESIGN  MANUFACTURING PLANNING & CONTROL  
Concurrent Engineering  
Continuous Improvement  
Just - in - time Systems  

PRODUCTION  DISTRIBUTION  
Re-manufacturing Consultants  
Personal Service  

DISPOSAL  SERVICE  
Consultants  

3. **Summary of the Position of European Manufacturing Industry.**

**Strengths:**
- High Tech: Aerospace, Pharmaceuticals, Electrical Engineering
- Medium Tech: Automotive, Chemicals, Mechanical Engineering
- Low Tech: Oil refining, Clothing (Fashion), Footwear (Fashion), Food and Drink, Paper and Publishing

**Weaknesses:**
- High tech: Office machinery and Data processing equipment, Instrument Engineering
- Medium Tech: Processing of rubber and plastics, manufacture of other transport means
- Low Tech: Textiles, Clothing (commodity), Leather and leather goods. Boat and ship building.

**Threats:**
- Failure to maintain and improve position in high tech sectors vis-à-vis US and Japan
- Competitive pressures in medium tech areas from Japan and NICs

**Opportunities:**
- Development of sophisticated product and process technologies based on good basic research. Incorporation of sustainability concepts into capital goods and systems.

**Drivers of Change:** Sustainability in consumption and production, sophistication in demand, increased service content of products, new markets.

**Responses needed:** More flexible and cleaner production systems, more integration between product design, manufacture, distribution and use, higher quality and reliability, less waste and experimentation with real products and processes, improved modelling and simulation.
References


ANNEX II

Technology Profile of European Industry

by Cranfield University

1. INTRODUCTION II-2
2. DEFINING TECHNOLOGY II-4
3. DEFINING “HARD” AND “SOFT” FACTORS II-8
4. TECHNOLOGY FORESIGHT STUDIES II-12
5. THE PERFORMANCE OF EUROPEAN MANUFACTURING II-22
6. CONCLUSIONS: A SWOT ANALYSIS II-29

References II-32
Appendix 1: Summary of 136 Key Technologies II-34
Appendix 2: Proposed Framework for Analysing IMS Attractiveness II-39
1. INTRODUCTION

The aims of IMS are “to prepare for the next generation of manufacturing technologies and systems through co-operative research and development” (IMS web page, www.ims.org). In a letter to CIRP, the “founding father” of IMS, Hiroyuki Yoshikawa (1990) states:

*The target is to establish a theory of manufacturing that can be transferred and usefully acts for constructing efficient factories in any region on earth. The basic idea is that manufacturing technology is a public asset of mankind. Presently however the knowledge of manufacturing is too much secretly owned by its creators, and hence causes too uneven a distribution of wealth among firms, countries and/or regions.*

Five common issues have emerged that are of concern to the transformation of manufacturing in advanced countries:

- **Globalisation**: locating production close to markets helps to reduce exchange rate risks, and to soften trade imbalances. Globalisation is inhibited by such factors as technology differences with respect to norms, standards and cultures.
- **The changing labour environment**: manufacturing is adversely affected by an increasing shortage of our best technicians who prefer careers in other parts of the economy. Action is required to improve the attractiveness of manufacturing industry.
- **The changing market environment**: consumer demand is becoming increasingly diversified and sophisticated, and the pace of change is increasing. Action is needed to accelerate product development and reduce time to market.
- **Environmental issues**: priorities must include the protection and improvement of the global environment through such measures as efficient utilisation of resources and recycling.
- **The spiralling cost and complexity of R&D**: the increasingly large scale nature of complex R&D projects is becoming beyond the scope of a single enterprise, or is seen as a wasteful use of resources. International collaboration of companies, public sector research institutions and academia is needed.

This work package seeks to develop a technology profile of European industry, to review technology foresight studies, and to evaluate European strengths and weaknesses. The terms of reference for this work package are listed in Annex III. The structure of this report is as follows:
• **defining *technology***: a brief review of the term is made, and related to product and process versions.

• **defining *hard* and *soft* factors**: we begin by distinguishing between hard technologies (machine driven), and soft technologies (driven by people and knowledge).

• **technology foresight**: summarises the country-specific reviews that have been undertaken by European governments, and compares them with North American and Japanese equivalents.

• **the performance of European manufacturing**: evaluates the position of European industry with particular reference to the other *triad* economies of North America and Japan.

• **conclusions**: develops an evaluation of the strengths and weaknesses of European manufacturing in terms of the evidence provided by the competitive position of industry and the technology foresight studies.
2. DEFINING ‘TECHNOLOGY’

It is important to attempt a definition of ‘technology’ relevant to this analysis. The definition used in the Dutch ‘Technology Radarí report (1998: Vol 4) is:

\[
a \text{tool or systematic collection of tools designed to manipulate the physical world in a reproducible and transferable way to affect purposeful change, and the knowledge of its application.}
\]

Manufacturing technology consists ëpartly of public and partly of non-public knowledgeí (Yoshikawa). While much of the knowledge may be in the public domain, it is the non-public knowledge that generates competitive power. Science on the other hand is ëknowledge about nature based mainly on cognitive reasoningí. Yoshikawa sees a link between the two: manufacturing technology has a ëuniversal justificationí, and should follow the same course as public developments in science.

Technology as a term can be applied to many different contexts. Two that are of particular interest to this report are product and process technology:

- **product technology**: focuses on the output of a manufacturing system, that is, what is being produced. Two product technologies referred to in Foresight studies are recombinant medicines and speech recognition.
- **process technology**: focuses on the manufacturing process itself, that is, how to produce a given product. Thus, IMS is focused on ëpreparing for the next generation of manufacturing technologies and systemsí.

The relative importance varies according to context. Thus, Innovation Strategies in Europeís top 500 Companies (Cordis, 1997: 7) concludes that ëfor most industries, product innovation as a goal is of equal or greater importance than process innovation, and occupies most of R&D personnelís timeí. On the other hand, a Technology Diffusion study (Cordis, 1997: 18) concludes that ëthe increase in technological sophistication of Japan which took place between 1970 and 1990 resulted primarily from a more intensive use of technologically advanced equipment and machinery, rather than from more R&D expenditureí.

A definition of manufacturing technology that is close to the IMS focus is that of advanced manufacturing technology (AMT, Pennings, 1987):

AMT is an automated production system of people, machines and tools for the planning and control of the production process, including the procurement of raw materials, parts and components, and the shipment and service of finished parts.

AMT is primarily a subset of information technology, and include computer-based technologies such as computer aided design (CAD), computer aided manufacture (CAM), computer integrated manufacturing (CIM), flexible manufacturing systems (FMS) and robotics (Dean and Snell, 1991). Heizer and Render (1996: 324) concur: “information sciences are the driving technology for both manufacturing and services.” In practice, product and process technologies must be strategically related to one another. Collins, Hage and Hull (1988) propose that the rate of change of product and process technology is governed by relative production volumes, illustrated in figure 1.

![Figure 1: Production System Development (after Collins, Hage and Hull, 1988)](image)

Using the diffusion of surface mount technology (SMT) as a research vehicle, Frohlich (1997) estimates that usage has grown to 65-70% of all applications over the last 15 years. The
application of this process technology can thus be reviewed in terms of different stages of the process life cycle, as illustrated in figure 2.

*Figure 2: Approximate Diffusion of Surface Mount Technology*

ëGiven the dynamic nature of process and product evolutioní, Frohlich argues, ëAMT adopters should use different strategies for learning before doingí, ie for the acquisition of knowledge:

- **early adopters:** should concentrate on learning that clarifies production process uncertainty. Sources of knowledge include vendors and experts. The goal of such pioneers is to select technologies that work with existing products.

- **late adopters:** should be prepared to rely more on simulations and experiments. Process uncertainty is relatively low: the pioneers have helped the AMT vendors to remove most of this uncertainty for the followers. Product complexity is higher because designers are now using the new capabilities for larger scale applications.

Dominant SMT paradigms ëdid not emerge until the early 1990sí. Before such paradigms were widely available, early adopters who emphasised more vendor and expert learning ërecorded lower start-up problems during adaptationí. Such conclusions are of interest to IMS projects aimed at emerging products where the process technology is uncertain.

A further consideration is that of life cycle logistics of products and processes, which covers the entire product life cycle from production through distribution, use and maintenance, and dismantling/recycling after use. These issues have been emphasised in an AIT report (1995):
The industry has to strengthen its competitiveness especially through innovation and improvements over the total business cycle from production conception to delivery and eventually recycling of materials. A study of life cycle assessment (Nordlist, 1997) observes that one of the main challenges today is for technical professionals and executives to get the information and data needed along the whole life cycle of materials, components and the product with a documented precision that makes it possible to compare a new solution with an existing reference solution with respect to technological performance and competitiveness.

One of the key actions in Framework 5 (1998:30) is *products, processes and organisation.*

The opportunities opened up by technology for increasing functionality, flexibility and intelligence in products and processes gives huge scope for strategies which boost competitiveness and job creation at the same time as dramatically reducing lifecycle and environmental impacts. Part of the objectives for this action are to improve the understanding of the soft aspects needed to integrate new methods of design and manufacture into relevant business processes. We turn next to an examination of what is meant by soft and hard factors in manufacturing.
3. DEFINING ‘HARD’ AND ‘SOFT’ FACTORS

Our next task was to clarify definitions of ‘hard’ and ‘soft’ technologies as applied in manufacturing industry. One piece of research that helps to draw out the difference is the IMVP study of the automotive industry worldwide. Womack et al (1990: 94) concluded that on average, automation accounts for about one third of the total difference in productivity between plants. But ‘what is truly striking is that - at any level of automation - the difference between the most and least efficient plant is enormous.’ Thus, for a given piece of technology, it is the ‘hidden’ factors that Yoshikawa refers to above that make the competitive difference. ‘Increasingly, the basis of competition is shifting away from ‘hard’ factors to ‘soft’ factors such as core competencies, speed to market, reputation and service (Panorama Special Feature, 1997). Support for such conclusions comes from Upton’s (1995) work in the American fine paper industry, showing that CIM actually reduces flexibility (measured in terms of product range and changeover times). ‘Systems often side-track manufacturing organisations from the tasks they should be doing well.’

The key issue is that a company’s competitive position at any point in time is less important than its rate of improvement in comparison with its competitors (Hayes, Wheelwright and Clark, 1988). Ability to compete in the 21st century in fragmented markets with shorter product lifecycles will not be achieved by technology (specifically, process technology) alone.

\[
\text{technology is not even the most important factor. It is important, no company will be able to compete without making use of technology, but organisation and people are equally important. There is no single element that should be given priority. A broad approach is needed, based on organisation, people and technology (FAST Monitor, 1990: 5)}
\]

Integrated manufacturing therefore needs more than technology in the traditional ‘artefact’ sense. Organisation and people can ‘provide solutions to manufacturing problems which lead to improved competitiveness.’ The Global Competitiveness report (1997:59) states that new technologies ‘hinge upon human capital. Computers are not a substitute for human brains. Rather, they work together.’ And the study of Public Policies to support Tacit Knowledge Transfer (Cordis, 1997:19) finds:

\[
\text{the importance of tacit knowledge (non-codified, disembodied know-how that is acquired via the informal take-up of learned behaviour and practices) appears to vary significantly}
\]
between sector, technology and market product groups. Its advantage to any particular firm depends on how it is generated, absorbed and protected against imitation and leakages.

It is essential to view technical change as a dynamic process to support the capacity of firms to innovate and change through continual learning. Thus, Framework 4 underscores the need to advance research and training in step with each other. The advancement of technology must be accompanied by the development of knowledge.

Spur (1997) illustrates the interaction of humans with machines in an industrial production system. In addition to the conversion of materials and energy, knowledge and information are needed. Thus, IT and the capability of people to gain knowledge and to use it are demanded, as shown in figure 2:

![Diagram showing the application of knowledge and information in a production system](image)

**Figure 2: The Application of Knowledge and Information in a Production System (after Spur, 1997)**

Information conversion can be described as hard technologies in that it is dependent on designs, systems etc that have already been proscribed. Soft technologies on the other hand are represented here by the knowledge conversion process, involving activities such as decision making and interpersonal communication.

In a study of the transfer of Japanese technology to the NSK Corporation at Ann Arbor (USA), Brannen et al (1998) go further. Some aspects of NSKís production system were transferred
fairly intact, while others met significant barriers to implementation. Sorting the technologies concerned was the first step in understanding what was at stake. Two sets of technologies were identified:

- **hard and soft technologies:** the distinction is based on the extent to which technologies and processes rely on accompanying organisational systems
- **explicit and tacit knowledge:** explicit knowledge is easy to document and to convert into operating procedures. Tacit knowledge is deeply embedded into a person’s consciousness, and is therefore difficult to access.

Figure 3 shows these two dimensions for technology classification. Technologies that were hard and explicit could be transferred relatively easily with little change. Technologies that were highly embedded (very ‘soft’) and with a high tacit knowledge base needed most conversion into the new environment of the production system (recontextualisation):

![Figure 3: Technology Characteristics and the Need for Recontextualisation](image)

There was less recontextualisation for autonomous equipment with an explicit knowledge base (referred to as ‘physical equipment’) and a lot more recontextualisation for social technologies requiring considerable tacit knowledge (referred to as ‘social processes’). The quadrants which
lie off the dotted-line diagonal (production tools and standard operating procedures) are between these two extremes. A step-like progression from ëhardí to ësoftí recontextualisation characterised technology transfers from Japan to NSK at Ann Arbor.

Soft factors and tacit aspects of the knowledge base have so far largely gone unrecorded. Because they are more difficult to measure, they fail to appear in competitive surveys, and are under-researched. Another Panorama Special feature (1997) states:

*a virtually exclusive focus on the ëhardí technological components and limited indicators such as R&D investments, therefore results in a highly incomplete and partial approach of industrial and technological policy design.*

The difference between advanced companies and laggards is much more related, the Panorama Special feature concludes, to the quality of their management than to their application of new technologies. In the knowledge economy the main factor of competitive advantage has become the ability to learn how to learn. The sustainability of different competitive factors can be represented as in table 1. The soft factor that ëencompasses the whole process - learning to learn - is the most difficult to imitateí.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Reaction Time of Competitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>lower price</td>
<td>2 months</td>
</tr>
<tr>
<td>publicity campaign</td>
<td>1 year</td>
</tr>
<tr>
<td>new product</td>
<td>2 years</td>
</tr>
<tr>
<td>new production process</td>
<td>3 years</td>
</tr>
<tr>
<td>distribution network</td>
<td>4 years</td>
</tr>
<tr>
<td>human resources</td>
<td>7 years</td>
</tr>
</tbody>
</table>

*Table 1: Sustainability of Different Competitive Advantage Factors*

A Technology Diffusion report (Cordis, Dec 1997: 18) concurs: simple indicators of R&D intensity are an inadequate measure of technological sophistication of industries.

Development of the knowledge base, then, is a key aspect of developing new technologies. But what are the issues at stake? The recently published Dutch ëTechnology Radarí report sheds considerable light, and will be considered in the next section.
4. TECHNOLOGY FORESIGHT STUDIES

Recognising that the economic strength of the industrial powers is under threat in an increasingly competitive world, it is desirable to consider various ways in which the future might unfold. Of particular interest to European countries is the nature of likely products and services that capitalise on the Community’s knowledge base. Once such products and services can be identified, research and development funding can be channelled where it can have most leverage. Shrinking Science and Technology (S&T) budgets, reducing technology lifecycles, spiralling R&D costs and risks, and the need to focus options on a few winners all point to more systematised processes for funding. Christian Perret, French Secretary of State for Industry, comments:

> Innovation is at the heart of the development of the economy and of industry in today’s modern societies, and technological innovation is its major component. As happens with a new product or service, or even in the advances to the production process, technology has become a veritable trump card in the competitiveness of companies and industrial employment.

Technology foresight may be defined as a systematic attempt to look into the long term future of science, technology, ecology and society. Its aim is to identify the areas of strategic research and the emergence of generic technologies likely to yield the greatest economic and social benefits (Second Report on S&T Indicators, 1997:277). The aim is to identify potentially important technologies early enough to facilitate their development and utilisation for socio-economic returns. Each European nation has undertaken a Foresight study with different ‘national’ criteria. Here, we review four of the major country studies and their conclusions.


The 1995 mini-Delphi study was conducted in collaboration with the Japanese National Institute of S&T Policy (NISTEP). This focused on a small number of key areas:

- material and process engineering for the future: photovoltaic cells and superconductivity
- microelectronics and the information society: cognitive systems and artificial intelligence
- biological sciences and the future of medicine: cancer research and nanotechnology
• the way out of damaging the environment: process and recycling of waste and climatic research

These study areas were broadened from 8 to 12 topics in the 1998 study. An evaluation of the German position confirmed that the US is in leading position in science and technology. However, in particular areas Germany was said to be better:

• in the sectors environment, energy, construction and transport Germany has a stronger R&D position than the US; Japan can be found in third position
• although the US has a leading position in the chemistry, production, bio-medicine, astronautics and large-scale experiments sectors, Germany is a strong follower and a close second.
• in the information and services sectors, the US leads, followed by Japan. Germany occupies third place.

In terms of action to advance the progress of S&T in Germany, the following polar diagram identifies the major priorities:

![Figure 5: Actions needed to Advance Science and Technology](image)
Thus, the priorities were seen as international co-operation and R&D infrastructure. Some 40% of the experts were, however, worried that there were potential negative socio-cultural side effects of the pursuit of S&T.


This project was aimed at linking two different but complementary approaches:

- the expression of the market’s technological requirements (market push)
- the dynamism of scientific progress (technological push)

A steering committee of 20 persons was tasked with identifying key technologies for the period 2000-2005. Two teams of consultants helped to facilitate. There were four project phases:

**Step 1: Identification of Selection Criteria:** the steering committee developed nine selection criteria for identifying the importance of a technology:

1. Existing or potential markets
2. Direct impact on the outside commercial world
3. Social and cultural acceptability or social and cultural encouragement necessary
4. Interest in obtaining or maintaining a competitive position on the product
5. Vulnerability and risks of industrial dependency
6. Contribution to the needs of the nation (defence, energy, environment, health, and culture)
7. Co-ordination with the nation’s industry
8. Capacity of each technology to take root in the nation’s industry
9. Total impact on competitiveness

**Step 2: Identification of the Technologies:** ten groups of experts (15-20 people in each) selected five groups of technologies under two main headings:

*Market technological needs:*

- health and environment;
- services and communication;
- transport systems
- consumer goods
- housing and infrastructures.
The dynamics of scientific progress:

- technologies of living beings;
- information technologies
- energy technologies
- "soft sciences" and technologies for creation, innovation and production;
- materials and associated technologies.

As a result, the steering committee agreed a list of 136 important technologies.

Step 3: Evaluation of French Standing: sought to evaluate the French position on these 136 technologies with respect to chief competitors both in the scientific and the industrial arena. These evaluations were drawn up firstly by using bibliographic searches on European, American and Japanese documents and secondly by asking various experts (from firms, R&D organisations and professional organisations)

Step 4: Selection of Key Technologies: From the results of the previous phase the 136 technologies were selected which seemed crucial for France. To do this the steering committee created a success versus attractiveness schema. The aim was to evaluate each of the technologies qualitatively, with the help of a restricted number of criteria:

- proven and noted success in France;
- attractiveness of the technology in question;
- key factors of success, that is the conditions whose joint presence is highly desirable for the successful fruition of a project.

A key technology, therefore, is a technology which is attractive, in which France has success and where key factors of success are present. After this final phase, 105 key technologies were retained on the list. These are marked by a bullet point in the list shown in appendix 2 to this paper. The Secretary of State for Industry subsequently published a Directory of Key Technologies (L’Annuaire des Technologies Clés) in 1995, which presents each technology in detail useful for all players in industrial and technological development.

Each file in the Directory includes a series of 5 indicators which inform the reader immediately of the principal characteristics of the technology and its market.
**diversity of involved industries:** number of different sectors of application. For more than 10 involved sectors the level of diversity is considered to be important. If there are less than 3 sectors it is considered weak; between 3 and 10 sectors it is considered average.

**maturity of the technology:** level of development of the technology and age of the market. If the technology has already been applied in industry for more than 2 years, it is considered well-matured; if it is at the stage of research, it is considered immature; in other cases the degree of maturity is considered average.

**intensity of competition:** number of players present in France and their degree of market share. If the number of players is greater than 10 and if three occupy more than two thirds of the market, the degree of intensity of the competition is considered strong; if the number of players is lower than 100 and if the share of principal players does not exceed 30%, the intensity of the competition is considered weak.

**forecast progress of the market** (in percentage of number of businesses). If the expansion of the market is greater than 25% per year it is considered strong; if it is less than 5% per year it is weak.

"**entry price**" for a prospective user. Level of investments necessary to use the technology and technical expertise to be acquired. If the total investment is greater than 1 million francs and if it is necessary to recruit specialists, the entry price is considered high; if the total investment is less than one million francs and it is not necessary to acquire special technical expertise, the entry price is low.

These criteria can be used to gauge the attractiveness of a market for potential partners. The 105 key technologies were classified into 5 groups in terms of the types of action required:

- **further R&D necessary:** eg transgenic animals, flat screens
- **promote technology diffusion:** eg neural networks, simultaneous engineering
- **particularly sensitive to public initiatives:** eg biomass conversion, pollutant modelling
- **industrial initiatives to be undertaken:** eg food preservation, voice recognition
- **autonomous development:** eg genome mapping, flash memories

Scientifically speaking, France and Europe occupy quite a strong position in 50% of the key technologies, and are weak in only 10%. But industrially speaking, the situation is less promising, with lower strengths (35% for Europe) and a higher proportion of weaknesses (21%
for Europe). A summary of the 136 technologies and 105 key technologies is made in appendix 1.

**The UK Technology Foresight Study: Office of Science and Technology, 1995:**

With a similar aim of linking market-led and technology push issues across the whole economy, the Technology Foresight Programme addresses some difficult questions:

- what are the likely social, economic, environmental and market trends over the next 10-20 years?
- which areas of R&D and underpinning science, engineering and technology best addresses those future needs
- how best can public funds be used to sustain an innovative science base to support future national prosperity and quality of life?
- to what extent should regulation, skills, educational facilities and other factors be taken into account?

In contrast to the French report, Technology Foresight sees the programme taking place in an arena where no one country can do everything that is possible. The structure of the programme was similar to the French: a Steering Group of industrialists, academics and government officials identified 15 sectors:

- agriculture, natural resources and the environment
- chemicals
- communications
- construction
- defence and aerospace
- energy
- financial services
- food and drink
- health and life sciences
- information technology and electronics
- leisure and learning
- manufacturing, production and business processes
- materials
- retail and distribution
- transport
Panels were appointed to each of these 15 sectors, and each has reported separately. Sector panels have assessed the current status of UK industry:

*a cautious approach is important because it is virtually impossible to predict the precise products and services which will have the greatest impact decades ahead*

The emphasis has therefore not been in picking winners, but on generating a flexible, well informed science, engineering and technology base that is able to respond rapidly to future needs. Thus, the solution to future growth is seen not simply as good science, engineering and technology but also as the realisation of a set of enabling factors:

- forward looking, technologically aware management, a workforce with relevant skills
- an awareness of customer preferences and attitudes
- effective transfer and exploitation of new technologies
- social, economic and regulatory policies that are conducive to innovation

These sectoral drivers were used to prioritise the zones in which different combinations of action are necessary to advance UK competence in the above 15 sectors:

- *advances and investment in basic science, engineering and technology (SET):* chemicals, materials, defence and aerospace, and health and life sciences
- *ability to exploit already foreseeable advances in SET and secure pull-through into internationally-competitive products and services:* IT and electronics, communications, food and drink, and financial services
- *stimulus provided by political, social and regulatory environments:* transport, retailing and distribution, and agriculture, natural resources and the environment
- *investment in human resources and deepening understanding of business processes and consumer preferences:* manufacturing, construction, and leisure and learning

These sectoral priorities were developed into generic SET topics, and these are listed in appendix 3 (to follow). A generic topic is a ‘concept, component or process, or the further investigation of scientific phenomena, that has the potential to be applied to a broad range of products or processes.’ Thus product and process technologies have been merged within the UK Foresight analysis. The generic topics were then prioritised using 6 criteria:
• economic and social benefits: that may be derived from a new market or technology opportunity
• SET opportunities: that make possible new developments in technology
• potential to apply: the comparative strengths and weaknesses: that will affect the ability of the UK to exploit opportunities ahead of other countries
• SET strengths: that will affect the ability of the UK to take advantage of opportunities compared with other countries
• cost of investing: in new SET
• the timescale: in which the new technology is likely to become available

These criteria were then lumped into two broad assessments: attractiveness and feasibility:

• attractiveness: the perceived benefits from a market- or technology-inspired development and the ability of the UK to harness the benefits in a market setting
• feasibility: the combination of expectation that a promising avenue of SET effort will yield tangible results with the ability of the UK science base to be at, or near, the leading edge in obtaining those results

As with the French study, a number of recommendations were made by the Steering Group as to how achievement of the generic topics should be taken forward:

• key priority areas: so promising that development was a top priority, eg optical technology, bioinformatics
• intermediate: needing to demonstrate world class capability. Strong linkage needed to application and exploitation, eg modelling and simulation, catalysis
• emerging areas: attractive market opportunities. Help needed in overcoming barriers to competitiveness, eg biomaterials, process engineering and control

The Dutch Foresight Study (eTechnology Radar), 1998: Ministrie van Economische Zaken

The Dutch Radar study investigated linkages between technology customers and suppliers for each of 15 strategic technologies in The Netherlands. Supply and demand were envisaged in terms of the relationships shown in figure 4:
Customers were split into two categories:

- **technology developers**: that develop or produce technology products.
- **technology users**: who use the technology from developers to produce some or all of their products or services.

On the supply side, there is the knowledge infrastructure, which is comprised of:

- **universities and other higher education institutes**: who educate people through degree courses and research, perform basic research, and keep abreast of current knowledge production.
- **research institutes**: which focus mainly on applied research, which is meant to be directly relevant to industry.
- **private research organisations**: in Europe and elsewhere whose results are accessible to European businesses.

"In any technology field, the more the technology developers are able to articulate a consistent, long-term view, the more likely it is that the research community will be responsive, and the more benefits will accrue to the [Dutch] economy." 

The relationships shown in figure 4 were investigated in four technology areas of particular interest: catalysis, software engineering, mechatronics, and bioprocess technology. Concerns about research and education in The Netherlands were listed in terms of five categories:
1. the quality of new researchers: while the technical training was well received, graduates were perceived as lacking experience of working in teams with different disciplinary backgrounds, and as lacking knowledge outside their own field of study. Industry has difficulty in finding technically trained people who have an awareness of business issues.

2. the quantity of university graduates: concerns are expressed about the falling numbers of undergraduates who read technical courses. There is a large gap between supply and demand for graduates in computer science and IT, and gaps are threatened in electrical engineering.

3. fragmentation of university research: industry may see university research as being too fragmented and not sufficiently responsive to technological change. Dispersion of knowledge makes it difficult to access and make use of the knowledge.

4. university responsiveness and multidisciplinarity: universities are not organised in a way that permits them to react quickly enough to rapidly changing research needs of companies working on products with short life cycles. Also, the content of courses of study was not being changed rapidly enough to keep up with developments taking place outside universities, especially in rapidly evolving fields like IT and gene technology. Individual professors tend to focus on the state of knowledge in their own field, leading to specialisation and possible remoteness of industry needs.

5. articulation of the needs of industry: university researchers complained of a lack of clear signals from industry to enable them to set their research agendas. SMEs are particular problems, with a notable lack of long-term perspective. Most often, companies in a given field will be unable to come up with a consistent view of their research needs, and rather fuzzy views need to be converted into concrete research questions.

A recent report on the future of Research and Technology Organisations (RTOs) in Europe (Cordis, Dec 1997:26) calls attention to the changing circumstances under which RTOs are operating. "Public sector funding is being reduced in many countries, and switched from core funding to contract-based awards. As a consequence, RTOs need to solve the dilemma of how to maintain their public duty role in helping unsophisticated SMEs and the dilemma of how to finance the renewal of their technology bases."

Conclusions

The individual country Foresight studies provide much valuable analysis of technology futures and how they may be met. What is missing is a European perspective. Framework 5 (1998:69) has called for analysis of technology foresight for the policy making process by the Joint Research Centre (JRC). Two additional foresight activities are proposed:
- *technology watch*: to facilitate identification of key S&T areas for the future and to anticipate their potential impact on emerging markets and social issues.

- *the impact of S&T on employment and competitiveness*: studying the effect of S&T on fostering competitiveness, growth and employment in Europe, and exploiting Europeís S&T potential for innovation and cohesion.

A number of strengths/weaknesses issues are apparent in the foresight reports, and these will be analysed in the concluding section.
5. THE PERFORMANCE OF EUROPEAN MANUFACTURING

We examine evidence from three major sources for this appraisal of European performance in manufacturing industries, and end with concluding remarks.

Industrial Competitiveness

This section is based on the OECD (1997) report on benchmarking business environments in the global economy. It is appropriate to begin however with observations on a new model of competitiveness from the IMD Yearbook (1997). Three new insights for policy making are proposed:

- **the economy of globality**: thrives on the “Anglo Saxon” model of performance, price and cost efficiency, deregulation, privatisation and extreme mobility. It is beneficial in terms of revenues and technology.
- **the economy of proximity**: thrives on the “Continental European” model of preserving social cohesiveness. This model trades off maximum efficiency and social responsibility with management of public deficits.
- **attractiveness**: the fundamental policy question of the location of value adding activities links the economies of globality and proximity. Attractiveness is influenced by taxes and the management of exchange rates.

The OECD review uses benchmarks for analysing country competitiveness on seven factors. Many of these (corporate governance and taxation, energy costs, telecommunications infrastructure and employment regulations) have been dropped from this analysis because they cannot be related to manufacturing sectors. We note in passing that these factors have a profound effect on attractiveness of country location, and also impact on the conditions under which high technology companies thrive. Data in the OECD report is at a fairly high level, but has been extracted and related with particular reference to manufacturing sectors as follows:

1. **R&D Infrastructure**: expenditure on the business enterprise sector (BERD) shows gradual decline in manufacturing while service sectors continue to grow. There is a distinction between the USA and the UK, where service R&D is greater than manufacturing (18-26% of BERD). France, Germany and Japan run at around 2-6% of BERD in service enterprises. Most of the expenditure in manufacturing goes into “coke, petrol, nuclear fuel, chemical and plastics” (20-30%), and into machines, instruments and transport equipment (40-60%).
2. Education and the Labour Force: few data of interest to technology development are given. One area of interest is the % university degrees by subject category. The major European countries all have about 10/12% of the 25-64 population as graduates. The USA has 24%. The breakdown by country is as follows (no data was available for France):

<table>
<thead>
<tr>
<th>Subject</th>
<th>USA</th>
<th>Japan</th>
<th>Germany</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Science</td>
<td>7.1%</td>
<td>5.3%</td>
<td>11.7%</td>
<td>6.8%</td>
</tr>
<tr>
<td>Natural &amp; Physical Science</td>
<td>10.3</td>
<td>7.3</td>
<td>17.6</td>
<td>17.1</td>
</tr>
<tr>
<td>Engineering &amp; Architecture</td>
<td>8.1</td>
<td>21.6</td>
<td>22.2</td>
<td>15.2</td>
</tr>
<tr>
<td>Law and Business</td>
<td>27.3</td>
<td>39.4</td>
<td>24.7</td>
<td>21.8</td>
</tr>
<tr>
<td>Human Sciences</td>
<td>47.3</td>
<td>26.3</td>
<td>23.7</td>
<td>39.1</td>
</tr>
</tbody>
</table>

3. Hourly Compensation Costs: here, the latest data available were for 1994. The breakdown by country by manufacturing sector is as follows:

<table>
<thead>
<tr>
<th>SIC</th>
<th>USA</th>
<th>Japan</th>
<th>Germany</th>
<th>France</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total manufacturing</td>
<td>16.86</td>
<td>21.07</td>
<td>26.90</td>
<td>17.04</td>
<td>12.86</td>
</tr>
<tr>
<td>Food, beverages &amp; tobacco</td>
<td>15.48</td>
<td>16.79</td>
<td>22.77</td>
<td>17.00</td>
<td>12.24</td>
</tr>
<tr>
<td>Textiles &amp; leather</td>
<td>10.60</td>
<td>12.76</td>
<td>19.30</td>
<td>13.54</td>
<td>8.69</td>
</tr>
<tr>
<td>Lumber &amp; furniture</td>
<td>12.85</td>
<td>16.81</td>
<td>23.44</td>
<td>14.77</td>
<td>10.30</td>
</tr>
<tr>
<td>Paper, printing &amp; publishing</td>
<td>17.41</td>
<td>22.43</td>
<td>26.48</td>
<td>20.41</td>
<td>14.91</td>
</tr>
<tr>
<td>Chemicals, rubber &amp; plastic</td>
<td>18.55</td>
<td>26.03</td>
<td>27.57</td>
<td>17.96</td>
<td>13.73</td>
</tr>
<tr>
<td>Stone, clay &amp; glass</td>
<td>16.97</td>
<td>22.26</td>
<td>24.62</td>
<td>18.22</td>
<td>12.05</td>
</tr>
<tr>
<td>Primary metal mfg</td>
<td>22.80</td>
<td>30.60</td>
<td>28.99</td>
<td>20.17</td>
<td>13.91</td>
</tr>
<tr>
<td>Fabricated metal &amp; machinery</td>
<td>19.74</td>
<td>22.33</td>
<td>27.92</td>
<td>17.36</td>
<td>13.36</td>
</tr>
<tr>
<td>Miscellaneous mfg</td>
<td>12.91</td>
<td>19.59</td>
<td>21.66</td>
<td>15.50</td>
<td>10.67</td>
</tr>
</tbody>
</table>

These hourly labour costs include all fringe benefits such as employer's social security payments.

Critical Technologies

An assessment was made of critical technologies in Europe covered by the EC research programmes (Narin and Albert, 1994). 13 technologies were selected which had been identified by the US Dept of Commerce as having the potential to create a multitude of new products and
services and to advance productivity and quality, and to enhance the likelihood of US success in international markets. These were:

- advanced materials
- polymers
- superconductors
- advanced semiconductor devices
- digital imaging
- high-density data storage
- high performance computing
- software
- optoelectronics
- artificial intelligence
- flexible CIM
- sensors
- biotechnology
- medical devices and diagnostics

The research methodology used patent citation analysis, whereby the number and characteristics of patented inventions relevant to the critical technologies are used as indicators of EU and competitor technological activity. One of the indices used in the study is illustrated in figure 6, and uses current impact index (CII). The CII compares a country's citation record to the patent system averages, ie average = 1.0. A CII of 1.1 indicates 10% more citations per patent. The more citations, the more likely that patent is to contain an important technological advance.

![Figure 6: % Share of Patents in 13 Critical Technologies v CII](image)
Overall, the US and Japan have rather similar performances on this index, but the EU is clearly behind and its performance has been deteriorating. In 1991, the CII for Europe was 1.2, compared to 1.6 for Japan and 1.7 for the US/Canada.

The authors concluded that the European position in critical technologies appears to be considerably weaker than in most technologies, and especially weak in electronics. Efforts of the EU over the previous 5-10 years to the study to stimulate and advance technological capability within Europe have not yet been successful enough to alleviate in any way the challenge of Japanese technological progress. A more fruitful use of EU funds would be in stimulating further development in the chemical, biomedical and material areas of EU strength, rather than fruitlessly challenging Japan and the US in the areas of their greatest strength.

**Made in Europe**

A study of competitiveness of European manufacturing was made which studied over 650 manufacturing sites situated in Germany, The Netherlands, the UK and Finland (Voss et al, 1995). Measures were made of six variables: total quality management, concurrent engineering, practices concerned with rapid new product development (concurrent engineering), lean production, manufacturing systems including automation, in-company and inter-company logistics practices, and organisation and culture, which included climate, teamwork, and organisational elements of best practice manufacturing. The central hypothesis of the study was that the adoption of best practices [in these six areas] will be linked directly to the attainment of high operating performance. Here, performance refers to the measurable results of a company’s processes in each of the six areas, including their business impact. Examples of process measures are work in progress and production cycle time; business impact measures include market share and customer satisfaction. The practice and performance measures had been calibrated against best practice worldwide (often referred to as world class).

Only 14 out of the 650 sites were considered to be world class. The top 10% of the sites (the leaders) exhibited better practice and performance in all areas. To be a competitive manufacturer on a world class basis, it was concluded, all round excellence is needed: there are no short cuts. The disappointingly low number of world class sites in Europe, coupled with the large number (30%+) that were considered vulnerable, raised the question of how well this is recognised. A comparison was made of participants in terms of how they rated themselves
relative to their competitors with their actual performance. While better companies were realistic, lower-performing companies showed a worrying gap between self-perception and actual performance. As well as being over-optimistic about where they stand, these managers may also fail to realise that world class status is a rapidly moving target. This may be related to the willingness of better companies to look externally to best practice benchmarking. Leading companies were far more likely to benchmark than lagging companies.

Across Europe, foreign-owned companies fared considerably better than those which were domestically-owned. Japanese-owned sites were particularly outstanding in both practice and performance; American-owned had much better performance on average than domestic firms. The one area where domestically owned firms were significantly better was in developing new products. This may be because many foreign-owned companies keep this function in their home country.

A number of areas were pointed out as examples of where European countries are meeting the challenge of becoming world class:

- **the German textile industry**: a strikingly high percentage of leaders shows how it is possible to succeed in this mature industry by moving up-market and focusing on quality and design. Many have in addition set out to adopt world class practice across a wide range, and are thus leading from all-round strength.

- **the UK electronic component manufacturers**: leading electronic companies are sophisticated purchasers who have developed suppliers by setting high standards and by helping those suppliers to develop world class standards themselves. Thus, many UK suppliers have developed superior practice and performance compared with other equivalent companies.

- **restructured sites in the former East Germany**: a major surprise for the study was that far more sites were moving towards world class than might be expected. New owners were able to adopt good practice on a faster and wider scale than in equivalent companies in the West.

On the other hand, there were two examples of areas that were ready for change: the German machine tool industry and the long tail of poor performing small firms in the UK.

An agenda for Europe was proposed to bring more companies up to world class standards by learning from successful companies, sectors and countries.
• **create world class companies, not vulnerable niches:** as with the German textile industry, sector wide efforts to create all-round strength can create a position that is robust and which will withstand threats from low-cost, high-quality competitors.

• **pull and push:** best practice can be pulled into sites from both high-performing parents, and from demanding customers. Best practice may also be pushed through education, government, trade associations and chambers of commerce.

• **be radical:** as shown by the emerging East German firms, driving new practices into old environments is possible.

• **invest:** investment does lead to productivity growth. But not just in plant and equipment: also in people and processes.

• **overcome inertia:** overcoming inertia at the company and industry level may be the biggest threat to European manufacturing. Exposure to overseas competition, benchmarking best practices and top management attention were the suggested remedies.

**Conclusions**

Broad-based economic indicators - such as the OECD data in the first section - tell us little about the relative health of European manufacturing. Sector data are by necessity very broad-based and dated, and the true compatibility between countries is problematic. It is possible to make broad deductions such as that Germany produces more medical graduates and (with the UK) more natural scientists than the USA or Japan. Also that wage rates in Germany and France are higher than the USA in most manufacturing sectors. And that the citation rate on patents is weak in most critical technologies in Europe, especially in electronics. But these are proxy measures, and it is not until we get down to the level of the firm as the unit of analysis that we can obtain a fuller picture of what is at stake. The *Made in Europe* study presents a mixed picture of excellence and example on the one hand, and of complacency and under-performance on the other. By researching factors like organisation and culture, this study attempted to engage with the so-called technological factors described in an earlier section of this chapter. We consider that it is essential that such factors are included in policy making.
6. CONCLUSIONS: A SWOT ANALYSIS

The evidence for technological capabilities and prospects for Europe is widely dispersed and partial. There are obvious problems in attempting to bring together such a variety of studies. This is a vast area, which has been probed by numerous studies, each of which has its own limitations. Much of the evidence is country-based rather than EC-based. "Soft" technologies have been under-researched and are still poorly understood. But in spite of such concerns, this is a summary and analysis of the evidence as it exists, brought together in terms of strengths, weaknesses, opportunities and threats to S&T in the future "key technologies".

**Strengths**

- both German and French foresight studies indicate a strong science base in key technologies. The French study indicates that the science base is strong in 50% of such technologies.
- the *Made in Europe* study points to excellence in German textiles, in UK electronics suppliers, and in restructured East German sites. Many European industries are currently competing very successfully on the world stage.
- a wide range of universities, research associations and companies are involved in technology research at different levels (EU, national, regional)

**Weaknesses**

- while national foresight programmes have been in existence for some years, there is a lack of co-ordinated foresight policy at EU level
- there has been a hitherto weak incorporation of "soft" technology factors in EU policy formulation
- while the science base may be strong, there has been a relatively weak industrial application of key technologies (only 21% of European applications are rated as "strong"). For example, technology transfer of rapid prototyping in the USA is facilitated by the Society of Manufacturing Engineers (SME), while the EU has no equivalent single body for technology transfer for RPT.
- there are insufficient world class companies in Europe. The German machine tool industry has been branded as complacent, and there is a long tail of under-performing small UK companies.
• the Dutch foresight study highlights several weaknesses of knowledge transfer in Europe. Falling numbers of graduates in technical courses, fragmentation of university technology research, slow responsiveness by universities to rapidly-evolving technologies and poor articulation of industry research needs are examples.

**Opportunities**

• IMS preaches international co-operation. This has been identified as a high priority development in the German foresight study, and is apparent from the piecemeal nature of European foresight studies up to now.
• the need to develop an effective R&D infrastructure was also highlighted in the German foresight study. Opportunities exist to address the fragmentation and other issues indicated in the Dutch foresight study referred to under “weaknesses”.
• develop relevant EU support for French actions for developing competitive advantage in key technologies and for UK actions for key priority areas.
• create world class companies through co-ordinated, sector-wide efforts such as German textiles and the Italian tile industry.

**Threats**

• fragmentation and nationalisation of EU efforts
• US and Japanese technology exploitation is generally better planned and co-ordinated across a wider front than in the EU, especially in key technologies
• erosion of the science base has led to poor performance in critical technologies with respect to the US and Japan
• inertia at company and industry levels has led to a poor record of comparisons against “world class” manufacturing practices in European countries, with only a handful of sites being rated as competitive with the best there is

It is important to note that most of the threats are self made, that is, their origins are within Europe rather than without. We have developed a conceptual framework for assessing IMS project attractiveness in terms of “hard” and “soft” technology implications together with the relative ease of moving the technology into or out of Europe. This is shown in appendix 3.
We end with advice from Porter (1990:631) on implications to government policy for S&T, which should have the emphasis of an *innovation policy* rather than just S&T policy:

- match S&T policy with the patterns of competitive advantage in a nation’s industry
- emphasise research at universities instead of government laboratories
- emphasise commercially relevant technologies (chemical, biomedical and material research rather than electronics?)
- forge strong links between research institutions and industry, by developing specialist research institutions focused on industry clusters or cross-cutting technologies, research contracts and by explicit dissemination mechanisms
- encourage research activity within firms (eg tax breaks)
- emphasise speeding up the rate of innovation rather than slowing diffusion through lengthy patent protection
- create a limited role for co-operative research: the main role of co-operative research should be to signal the importance of emerging areas of new technology, and to stimulate research at the level of the firm.

These are all profound points, but none of these elements of advice for government S&T policy seems at odds with what we have found in our review. Many business environment factors, such as corporate governance and taxation and employment regulations, affect the willingness of key technology start-ups to locate in Europe.
References:

- **Brannen MY**, **Lik er JK** and **Fruin WM** (1998): Factory to Factory Knowledge Transfer from Japan to the US, the Case of NSK, Remade in America, Oxford University Press (forthcoming).


- **Cordis** (1997): Innovation in Europe, 10th Dec.


- **FAST** (Forecasting and Assessment in S&T), (1990: Organisation, People and Technology in European Manufacturing by Paul Kidd, Nov.


• **Spur G** (1997): Optionen zukünftiger industrieller Produktionssysteme, Akademie Verlag, Berlin

• **Studie zur globalen Entwicklung von Wissenschaft und Technik**, (1998): Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie

• **Technology Radar**, Volumes 1-5, Ministerie van Economische Zaken, Den Haag

• **The UK Technology Foresight Study**, (1995): Office of Science and Technology

• **The World Competitiveness Yearbook** (1997): IMD, Lausanne


• **World Economic Forum** (1997): The Global Competitiveness Report


• **Yoshikawa, H** (1990): Competition from Product to Knowledge in memo to CIRP Council Members
Appendix 1. Summary of 136 Key Technologies

**Health and living technologies**

1. Genetically engineered animals
2. Monoclonal antibodies
3. Biomaterial for medical equipment
4. Genome mapping
5. Preservation of foodstuffs
6. Extraction, separation, purification ("downstream processing")
7. Medical images
8. High efficiency vegetable raw materials for biofuels
9. Recombinant medicines
10. Rapid methods of microbiological detection
11. Predictive microbiology
12. Genetic modification of plants
13. Pharmacology based on cellular exchange
14. Automatic sequencing of DNA
15. Molecular probes
16. Blood substitutes
17. Cardiac replacement
18. Systems for producing recombinant proteins
19. Techniques linked to treating hospital patients in the home
20. Technologies for non-invasive surgery
21. Gene therapy
22. Genetically-engineered vaccines

**The environment**

23. Decontamination and rehabilitation of soil
24. Biological purification of waters and treatment of sewage
25. Neutralisation and storage of nuclear wastes
26. Neutralisation and storage of non-destructible wastes
27. Environmental measurement
28. Modelling and impact of pollutants
29. Cleansing without waste water
30. Recycling of polymers
31. Underground storage of wastes
32. Treatment of urban wastes
33. Treatment and quality control of drinking water
34. Sorting, storage and compacting of urban wastes
35. Utilisation of compactors (?) for waste disposal

**Information and communication technologies**

36. Algorithms for compression and decompression of sound and images
37. Client server architectures
38. Massively parallel architectures
39. Batteries for portable electronic equipment
40. Cables and optical fibres
41. Components for interconnection and interface
42. Microwave components
43. Opto-electronic components
44. Designing and manufacture of low current components
45. Connecting different applications or middleware
46. EDI
47. Flat screen technology
48. Ergonomics of keyboard and screen
49. Management of intelligent networks
50. Computer-generated images
51. Linguistic engineering
52. Virtual interfaces
53. Flash memory
54. Mass memory
55. Programming tools (software engineering)
56. Object oriented programming
57. Speech recognition
58. Pattern recognition
59. Neural networks
60. Security of transactional systems
61. Video servers
62. Agent based systems (literal translation- the concept is explained in the book - Les Technologies cles)
63. Navigational systems for multimedia services
64. Real-time systems
65. Low-level submicronic technologies
66. Software testing and certification
67. Broadband transmission and switching

Transportation

68. Improving recycling of vehicles
69. Batteries for electric vehicles
70. Vehicle air-conditioning
71. Very high tension electronic components
72. Design of vehicle control panel and steering
73. Dynamic control and management of traffic flow
74. Reduction of motor fuel consumption
75. Shock absorbent materials
76. Clean (combustion) engines
77. Slot control vehicle systems
78. Reduction in the weight of road vehicles
79. Reduction in aerodynamic noise (planes, High Speed Trains - TGV)
80. Reduction in road vehicle noise
81. Simulation and protection for electromagnetic compatibility
82. Steel wheel on steel rail system technologies for very high speed

Materials

83. Polymer alloys
84. Surveillance and characterisation of damage to coinage
85. Structural bonding
86. Construction of components in an organic matrix
87. Complete software models for materials and their development processes
88. Adaptative materials
89. Materials for high temperature production processes
90. New textile fibres
91. Piezo electric (electro-crystal), ferroelectric and magnetic polymers
92. Coatings for multifunctional surfaces
93. Synthesis of complex molecules

**Energy**

94. Medium power electronic components
95. Large systems control systems
96. Biomass conversion
97. Low energy domestic lighting
98. Large systems maintenance
99. Clean and safe nuclear power
100. Photo-electric cell technology
101. Oil and gas production from deep wells
102. Efficient oil recovery
103. Storage and distribution of liquefied natural gas
104. Processing of gases resulting from the combustion of coal and wastes

**Buildings and infrastructures**

105. Optimum performance concrete
106. Maintenance and renovation of water supply and sewage systems
107. Management of airflow in buildings
108. Management of water resources
109. Tools for the detection of deterioration in public works
110. Techniques for the execution of underground works

**Organisational and accompanying technologies**

111 Value analysis, functional analysis, designing cost/aim
112 Documentation and provision of manuals
113 Ergonomics of workstations and office equipment
114 Ergonomics of mass market products
115 Electronic tagging
116  • Real time management of logistic information applied to the management of traffic flow
117  • Simultaneous engineering
118  • Methods of quality assurance
119  • Measurement of sense data
120  • Models to improve reliability and risk simulation
121  • Modelling the sociology of organisations
122  • Tools for managing complex projects
123  • Rapid prototyping
124  • Reliability

Production, instrumentation and measurement

125  • Intelligent sensors
126  • Catalysis
127  • Continuous flow and continuous processes for steel making
128a • Cutting technology using water jets
128b • Cutting technology using lasers
129  • Disposal of products at end of life
130  • Equipment for units of semiconductor production
131  • Non-destructive experimentation
132  • Microtechnology
133  • Processes for membrane separation
134  • Robotics in a hostile environment
135  • Mass spectrometry
136  • System for management of high levels of purity for electronics

**Note:** technologies marked by a dot (•) are designatedétablissements Clès (key technologies).

Source: *LiAnnuaire des Technologies ClÈs*, Direction GÈnÈrale des Strategies Industrielles, September, 1997
Appendix 2. Proposed Framework for Analysing IMS Attractiveness

As part of our work in researching this project, we developed the following outline framework for analysing the relative attractiveness of IMS projects:

- **Hard-soft dimension:** measures the extent to which technologies and processes rely on accompanying organizational systems.
- **Mobile-immobile dimension:** measures the relative ease of moving a given technology into or out of Europe. Immobility is influenced by unique availability of labour skills, local availability of natural resources, difficulty of transporting the technology, incompatibility of the technology with non-European infrastructure, refusal to subcontract 'core' technology, and by local cost advantage.

As an approximate example, this model may be populated by some of the processes that make up parts for an aircraft:
Note that priorities are assigned at the major component/subassembly level rather than at the completed product level.

Other things being equal, the preferred position for projects would be to the left of the framework, ie in the ‘immobile’ half. This would imply that it is difficult to relocate manufacture to another part of the world. It is also preferable for projects to be in the bottom left corner of the framework, because it such projects have a leveraged effect on manpower. By definition, ‘soft’ projects are human-centred processes, and therefore have most benefit on employment. A priority sequence may be proposed for project attractiveness as follows:

Thus, the most attractive from an investment point of view are the soft, immobile projects. The least attractive are the soft, mobile projects.
This framework is based on the dimensions of hard/soft technology and on ease of mobility. There are clearly other issues at stake on the choice of projects, and these have to do with the product rather than the process emphasis. We continue this paper by considering key product technologies for Europe.

We have tested this framework on a number of academic and industrial experts in the UK and in Germany, and so far the reaction has been supportive in terms of what the framework is trying to achieve.
ANNEX III

Background of the IMS study

1. Original proposal for the SWOT study III-2

2. Terms of reference for the sub-contracts III-6
   2.1. General literature review and cases description III-6
   2.2. Technological capabilities and prospects III-8
1. Original proposal for the SWOT study

‘Strategic options for European Manufacturing Industry vis-à-vis IMS Initiative’

1.1. Objectives

The objectives of this study are:

1. to give an overview of the position of manufacturing industry operating in Europe with respect to other locations, in terms of the current situation of its strengths and weaknesses, and in a more future oriented respect regarding opportunities and threats.

2. to elucidate the technological components of the general SWOT overview distinguishing between “soft” (i.e. technology in the sense of ‘know-how, -who, -why’, - production and general business strategy, design, quality and logistics, organisation production of human resources, knowledge management, techniques for market and techno-economic intelligence, etc.) and “hard” (automation, process technologies, ICT, robotics, manufacturing systems, etc.) aspects, as well as the integration of the two.

3. to identify possible options for the basis of a European strategy regarding its participation in the Intelligent Manufacturing Systems (IMS) initiative.

1.2. Work Content

The work will be divided into four workpackages and involve the organisation of two workshops and a final presentation, as described in the following:

WP1. Overview

This will consist of two parts.

- The first will involve taking stock and of the most recent data, statistics and reports regarding the situation of manufacturing industry in Europe in terms of foreign trade, specialisation, R&D expenditure, technology intensity and dependency, etc. at a fairly aggregate statistical level. Analysis
and interpretation will be made to the extent possible, especially with a view to uncovering interesting situations and information of relevance to this study as a whole, which may be disguised by the aggregate level data. The main output of this will be a commented summary of the present apparent strengths and weaknesses of manufacturing industry in Europe.

- The second will take a more forward looking stance, aiming at summarising the most up to date wisdom and conjecture about the future of manufacturing industry in Europe, the threats it faces as well as the opportunities. This will be placed in the context of the general evolution of manufacturing industry worldwide, and the emergence of new paradigms, new players, new markets and geopolitical location strategies. The aim would be to expose contrasting views and opinions that could be held up to debate for the purposes of reflecting on possible IMS strategies.

The significant gaps between the strengths and weaknesses in manufacturing capability and the profile of companies equipped to avail of the opportunities in the expected future scenario will be described.

**deliverable 1**: a two part report (chapters 1 and 2 for the final report)

-effort required: 10 person-days, part reserved till after workshop 1 to finalise as a function of the workshop conclusions.

**Workshop 1**

This will involve all the parties conducting the study, IMS representatives and secretariat officials, and up to five invited experts. The aim will be to reflect on the findings of WP1 and advise with regard to the execution of the following stages of the study. It would be expected that someone from outside the study group make a presentation regarding the history of the IMS initiative and its present status worldwide and within Europe.

**deliverable 2**: meeting conclusions and revised deliverable 1.

**WP2. Technological capabilities and prospects for manufacturing in Europe**

The work here will also be conducted in two parts, corresponding respectively to the ‘soft’ and ‘hard’ technological factors mentioned above in the objectives, that can be recognised to be ever more crucial in conducting successful manufacturing business. At the general level, the first task will be to draw up clear definitions to distinguish between ‘hard’ and ‘soft’ technologies. The work will then
proceed via an exhaustive literature review to summarise what are the present strengths and weaknesses of manufacturing industry and knowledge infrastructure expertise and capability (Universities, consultancy services, R&D centres, ..) in Europe in each of these two domains separately, as well as the prognosis for future development (opportunities, threats). This overview should be as broad and generic as possible, though not without appropriate examples and citations to render the resulting report as clear as possible.

deliverable 3: report in two parts (draft chapters 3 and 4)
effort required: 15 person-days

WP3. Cases
The objective of this part is to further elucidate the significance of the findings in WPs 1 and 2, by placing the previous findings in the context of a number of specifically chosen sectors. The proposal is that the cases chosen will correspond to I) an example of a sector which is primarily bound in its operation to the European area, and II) a sector which is active and important for Europe, but very much operating in an open international/ global arena. The case descriptions will be developed in a way which reintegrates the soft and hard technological aspects in line with the manufacturing reality. They will also serve to illustrate what is at stake with regard to European technological deficiencies and the options available with regard to compensating for the same.

deliverable 4: case descriptions (draft chapter 6)
effort required: four person-days

Workshop 2
This will involve the same participants as in Workshop 1. The findings of WP2 and WP3 will be reported and discussed with specific reference to the IMS initiative. In particular, the workshop will set out to test and debate the relevance of the study findings up to this point with regard to a European IMS strategy.

deliverable 5: workshop report and revised deliverables 3 and 4

WP4. Synthesis, Conclusions and Recommendations
In this final task, the various chapters will be combined and edited into a single report and a final chapter of Conclusions and Recommendations in line with the main objective of this study, be drawn up.

**Deliverable:** final report and summary

**effort required:** six person-days

3. Management

The work will be conducted by the IPTS in-house, and through small sub-contracts with institutes from the IPTS network of collaborators. One sub-contracted package will be WP1 and WP3, and the second will be WP2. IPTS will ensure all other necessary co-ordination for the work and administration of the project. This includes all editorial duties on deliverables produced, producing final conclusions and recommendations, organising the two workshops, administering two sub-contracts, etc.
2. Terms of reference for the sub-contracts

2.1. General literature review and cases description.

2.1.1. Literature review

This part involves the construction of an overview which focuses on two aspects of the current capability profile of European manufacturing industry. The initial aspect examined will be the current position of industry as reflected in a range of indicators covering the technology trends within which industry is operating leading to an assessment of the main strengths and weaknesses of European manufacturing industry. The second aspect of the situation which will be examined will be the currently expected future for industry, including the opportunities and threats facing European industry and the emerging technological and organisational frameworks in which it will operate.

Scope
This will cover a range of sectors which will be broad enough to ensure that all types of industrial structure and configuration of demand pattern are included. The studies will ensure that, while generic capabilities and problems are the principal focus, significant sectoral issues are not overlooked.

Tasks
• Identify recent literature on technology trends, technology performance and technology needs in industry. In addition, examine relevant issues such as trade and technology dependency/autonomy using ideas such as those developed in a paper by Pierre-André Buiges and Alexis Jacquemin “Structural Interdependence between the European Union and the United States: Technological Positions”. Summarise information at a sectoral level, in so far as analysis is possible.
• Compare situation between US, Japan and Europe and with other countries in OECD databases.
• On a relevant sectoral basis extend the comparison to other emerging economies in SE Asia.
• Prepare a commentary which focuses on the strengths and weaknesses of European manufacturing industry.
• Review the drivers of change in the industrial area and focus on the clearly evidenced trends which require R&D responses from industry.
• Identify the range and scope of the principal threats that exist to European industry either from current weaknesses or from emerging developments in which Europe is not adequately equipped. Establish the views of industry experts and review the foresight studies for indications of the projected development of European manufacturing.
• Reflecting the strengths of European industry, identify opportunities, particularly those in which additional collaboration in R&D could advance the strengths.
• Prepare a commentary which places this SWOT analysis in a context which looks for synergy with IMS concepts.

2.1.2 Cases description

The objective of this part is to further elucidate the significance of the findings in the literature review, by placing the previous findings in the context of a number of specifically chosen sectors. The proposal is that the cases chosen will correspond to I) an example of a sector which is primarily bound in its operation to the European area, and II) a sector which is active and important for Europe, but very much operating in an open international/ global arena. The case descriptions will be developed in a way which reintegrates the soft and hard technological aspects in line with the manufacturing reality. They will also serve to illustrate what is at stake with regard to European technological deficiencies and the options available with regard to compensating for the same.

Deliverables

1. Report of literature review in two chapters, suitable for inclusion in final project report following a review workshop.
2. Report on cases description.
2.2. Technological capabilities and prospects

2.2.1. Introduction

As part of an overall literature review based SWOT analysis of manufacturing industry in Europe, this study involves the examination of two aspects of the technological profile of European Industry. These aspects are classified as “hard” and “soft” technological factors which govern the operation and development of manufacturing industry. The influence of these aspects of technology must be understood separately and in their interaction to guide any future strategy in the area.

2.2.2. Scope

This will cover not just the capabilities within European manufacturing industry but also the knowledge infrastructure of universities, consultancies and research institutes in terms of developments and applications of those elements which are encompassed in the idea of “intelligent manufacturing”. The position of Europe in terms of its capabilities and deficiencies will be outlined.

2.2.3. Tasks

- Identify recent literature on “hard” and “soft” technologies as applied in manufacturing industry. For example, refer to the French Ministry of Industry study on “100 Key Technologies” for an outline of the concepts which link organisational forms and developments to traditional product/process technologies. Clarify definitions to provide a working basis for distinguishing between these concepts.

- Summarise the strengths and weaknesses of manufacturing industry in Europe with particular reference to the situation in the US and Japan.

- From the literature review summarise the capability position of Europe’s knowledge infrastructure (universities, consultancies and research institutes) in respect of “hard” and “soft” technology domains.

- Prepare a commentary which focuses on the strengths and weaknesses of Europe.
• Review the future paths of these domains and identify any aspects which may need R&D responses by European industry.

• Identify the range and scope of the principal threats that exist to European industry either from current weaknesses or from emerging developments in which Europe is not adequately equipped.

• Reflecting the strengths of European industry and infrastructure, identify opportunities, particularly those in which additional collaboration in R&D could advance the strengths.

• Prepare a commentary which places this analysis in a context which looks for synergy with IMS concepts and which could form the basis for viable strategies by Europe.

• Suggest sectors or technologies which would benefit from IMS developments.

2.2.4. Deliverables

Report in two chapters, suitable for inclusion in final project report, following a review workshop.
ANNEX IV

Participants in the two study workshops,

Brussels, EC DG-XII,

21-22 January 1998 and

19-20 March 1998
Participant in workshop 1:


• **EC - IMS Secretariat**
  Dietlind Jering, Angel Pérez Sainz, J. Suominen, O. Nielsen

• **IPTS staff**
  James Gavigan, Hector Hernández

• **Project contributors**
  Eamon Cahill, Irish Productivity Centre
  Alan Harrison, Colin New, Fred Lemke, Cranfield School of Management

• **Experts from the European Industrial Advisory Group**
  Manuel Moron García, formerly at Dragados, Spain.
  Jean Claude Moreau, Group Schneider, France.
  Luigi Francione, ex-Executive Vice President, FIAT, Italy.

• **Invited Commentators**
  Nicholas Oulton, Senior Research Fellow at the National Institute of Economic and Social Research, UK.
  Fritz Klocke, Director of the “Institut für Produktionstechnologie”, Aachen, Germany.
  Massimiliano Mandelli, Technical Dept. Manager of UCIMU, Milan, Italy.
  Pierre Ribal, Former Director of the R&D Department of Group Pechiney, France.
  Odd Myklebust, Research Manager at SINTEF, Trondheim, Norway.
Participant in workshop 2:


- **EC - IMS Secretariat**
  Dietlind Jering, Angel Pérez Sainz, W. Puymbroeck, R. Haendler

- **IPTS staff**
  James Gavigan, Hector Hernández

- **Project contributors**
  Eamon Cahill, Irish Productivity Centre
  Alan Harrison, Fred Lemke, Cranfield School of Management

- **Experts from the European Industrial Advisory Group**
  Manuel Moron García, formerly at Dragados, Spain.
  Jean Claude Moreau, Group Schneider, France.
  Luigi Francione, ex-Executive Vice President, FIAT, Italy.

- **Invited Commentators**
  Nicholas Oulton, Senior Research Fellow at the National Institute of Economic and Social Research, UK.
  Martin Reuber, “Institut für Produktionstechnologie”, Aachen, Germany.
  Massimiliano Mandelli, Technical Dept. Manager of UCIMU, Milan, Italy.
  Pierre Ribal, Former Director of the R&D Department of Group Pechiney, France.
  Odd Myklebust, Research Manager at SINTEF, Trondheim, Norway.