TECHNOLOGY STRATEGY AND THE INWARD TRANSFER OF FOREIGN TECHNOLOGY IN THE UK MACHINE TOOL INDUSTRY

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Research Thesis Submitted for the Degree of Doctor of Philosophy

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October 1990

SUMMARY

The international competitiveness of machine tool manufacturing companies in the UK is in long term relative decline. This is evident in diminishing UK shares of world production and exports, increasing import penetration and the higher technical sophistication of imports over exports.

Executives in the industry tend to explain declining performance by referring to exogenous factors beyond their control, such as adverse currency movements, weak demand and conservatism among users in the domestic market. Rising imports are often explained away as the inevitable consequence of growing specialisation and internationalisation. These claims are not without foundation but they are at a high level of generalisation and do not shed light on the managerial problems of adapting to unprecedented levels of foreign competition and technological change.

Most policy prescriptions for restoring competitiveness in the 1980's have highlighted awareness of the international dimension and the contribution of technology in overall strategy development. One strategic option finding increasing interest among executives in machine tool manufacturing companies and receiving substantial encouragement from the UK Government, is that of supplementing indigenous technological capability by increasing the "inward" transfer of foreign technology.

This dissertation examines the sourcing of appropriate machine tool technology from overseas via foreign direct investment, joint ventures and licensing arrangements. The approach is multidisciplinary and focusses on the strategic management of technology at the level of individual business units, giving due consideration to existing patterns of foreign ownership and collaboration. Particular emphasis is placed on understanding how foreign technology emerges as a strategic option, the conditions under which it is assimilated and the relative merits of the three modes of inward technology transfer.

The research shows that providing a critical mass of indigenous skills and capital expenditure can be maintained, the inward transfer of foreign technology offers considerable potential for achieving and sustaining a future level of technological capability comparable with that of international best practice. To facilitate effective exploitation of these opportunities, however, the priorities are threefold: firstly, executives must pay greater attention to competitor analysis and monitoring technological developments worldwide; secondly, many companies should use foreign technology to reposition themselves in existing segments and/or redirect their strategies towards growth segments; and finally, there is an urgent need for management/organisational development in machine tool companies to create a balanced internal environment which is more receptive to the potential "total" benefits embodied in both internally generated and foreign technology.

ACKNOWLEDGEMENT

Many people helped and encouraged me over the course of this research. My first debt is to the senior executives in UK and US machine tool companies who generously gave of their time and were willing to share their experiences. Without their interest in my work and permission to gain access to decision makers, this research would not have been possible.

Thanks are also due to my former employer, Coventry Polytechnic, for providing financial support and allowing me to carry out the bulk of the field research; and my current employer, Cranfield School of Management, for allowing me the time to complete the writing. To colleagues in both institutions and to Karena Scowen, who typed the final manuscript, I offer my sincere thanks.

I am especially indebted to two people, for quite different reasons. The first is Brian Parkyn, a former director of Scott Bader Company. It was he who first introduced me to technology transfer and was prepared to let a raw business graduate loose in the stimulating world of international business. The second is Brian Houlden, Institute of Directors' Professor of Business Studies at the University of Warwick, who supervised this research. His continuing support and constructive criticism, together with an understanding of the pressures on part-time doctoral researchers, is much appreciated.

Among the many academic writers, there are a few whose work I regret not finding the time to read as a practising manager and have now come to admire. If a measure of the value of their work is the number of times it is re-visited, then four writers spring to mind as influential in shaping my thinking: Professors Henry Mintzberg, Bela Gold, John Dunning and Thomas Allen. To these and other writers too numerous to name, I owe an intellectual debt.

And finally, to my wife, Christine, and children, Rebecca and Matthew, I owe special thanks for putting up with the disruption to family life for far too long. It is to my family that I dedicate this research.

A F Millman

CONTENTS

SECTIONS	PAGE

APPENDICES

LIST OF FIGURES

LIST OF TABLES

PAGE

1. INTRODUCTION

1.1 THE PROBLEM OF DECLINING COMPETITIVENESS OF THE UK MACHINE TOOL INDUSTRY

The international competitiveness of the UK machine tool industry, like that of many other engineering and manufacturing industries, is in long term relative decline. Arresting this decline in the face of intense foreign competition has been the concern of Government and machine tool manufacturing companies throughout the 1980's.

Machine tool manufacturers have been labelled by the financial press as 'ailing and unglamorous' and 'exhibiting lacklustre performance'. Of the few manufacturers who have performed well, it has invariably been relative to the rest of their industry and not compared with investment opportunities elsewhere. Under pressure to earn short-term profits, the major engineering groups have shown decreasing strategic commitment to their machine tool businesses, as evident in the lack of investment and continuity of ownership.

Executives have frequently attributed poor and erratic performance to uncontrollable factors such as the vagaries of world trade, business cycles, underlying weaknesses in the UK domestic economy and reluctance on the part of UK machine tool users to embrace automation. High import penetration has tended to be dismissed as part of the wider trend towards specialisation and internationalisation within the industry. Executives have been less vociferous about their own shortcomings but quick to offer opinions on the demise of long-established names in the industry and to point to foreign competitors in strategic trouble. Notwithstanding the impact of unfavourable external factors, especially currency movements, few executives could find comfort in the feeling that these problems are not a peculiarly UK phenomenon.

When the UK economy plunged into recession in 1979/80, manufacturers sought retrenchment as they had done in earlier cyclic downturns. Gradually it was realised that this was to be the most severe and prolonged recession since the second world war. To say that executives were complacent and ill-prepared for the downturn is to understate the magnitude and complexity of the strategic problem. The stark reality was of late response to a longer term trend in deteriorating international competitiveness. Retrenchment, as the traditional recipe, became increasingly untenable on its own and simultaneous strategic change along several key dimensions was required.

Among the competitive deficiencies exposed by the recession were mature product lines, outdated skills and equipment, poor product quality/reliability, high costs and low productivity by international standards. To survive in the short-term and reposition themselves ready for the upturn, most manufacturers needed to quickly catch-up in their core technology and/or diversify into growth areas.

This research aimed to address four important inter-related issues in the response of machine tool manufacturing companies in the UK to restoring competitiveness:

(a) the strategic problem of ensuring that product technology and manufacturing technology are at least abreast of international best practice;

(b) the potential for improving competitiveness by supplementing indigenous machine tool technology via the inward transfer of foreign technology;

(c) the managerial processes by which technological issues and specifically, technology transfer enter the overall decision-making framework;

(d) the implications of strategic reorientation for management/ organisational development.

The motivation for this research is rooted in my industrial-experience, initially in engineering design and later as a commercial manager with responsibility for international operations, including technology transfer. Exposure to the dynamics of the international business environment had a profound influence on my personal development. Consequently, technological and international aspects of strategy development have continued to provide the driving force behind my research and consultancy work on taking up academic appointments at Coventry Polytechnic in 1980 and Cranfield School of Management in 1988.

Earlier experience had focussed my attention on the inadequate knowledge and skills base on which many strategic technological decisions are taken. Executives in UK-owned and foreign-owned engineering companies appeared, like myself in previous jobs, to be working in isolation, with very little in the way of a practical framework against which to interpret their own limited experiences and evaluate opportunities. Simultaneously, Government policy prescriptions regarding inward foreign direct investment and collaboration were emerging which had been formulated at a high level of aggregation, based on seemingly superficial knowledge of the nature and scale of existing inward transfer arrangements. Selection of the UK machine tool industry for research satisfied my personal criteria of examining strategic aspects of electro-mechanical technology, coupled with a high degree of foreign participation and competition. The following characteristics of the industry illustrate its strategic importance and why consideration of the international dimension in technology strategy development is a fertile area for research:

(a) The "products" of the machine tool industry provide the "processes" of a wide range of user industries. This interdependence is characterised by what the historian LTC Rolt (1965, p12) referred to as 'the propogating power' of machine tools, whereby a new or improved machine solves a particular production problem, which in turn makes possible the better construction of a similar or different kind of machine. In this respect, the comparatively low UK production (£413 million) and employment (23,000 people) in 1983 did not adequately reflect the industry's overall impact on the national level of competitiveness and belied its role as a strategic defence industry.

(b) Machine tools is an international market with approximately 40-45 percent of world production entering the export market in the 1980's. Evidence of declining international competitiveness is not difficult to find. UK manufacturers have claimed a reducing share of world production and exports over the last two decades. UK import penetration has increased dramatically. The technical sophistication of imported machines is higher than that of exported machines, and over the period 1975-83, UK machine tool production declined at a greater rate than the "all manufacturing" index and the index of production for major customer industries such as motor vehicles, mechanical and electrical engineering.

(c) Technological change in the machine tool industry is increasing in both pace and complexity. Firstly, the technologies associated with mechanical engineering design, production engineering, microelectronics and computing are converging; leading to new demands on managerial and technical capabilities to deal with machine "systems". Secondly, many of the changes have originated outside the traditional boundaries of the industry and outside the UK. These trends present major strategic challenges for machine tool manufacturers as they struggle to maintain competitiveness in stand-alone machines and to exploit the opportunities for higher added value inherent in the supply of machining cells and flexible manufacturing systems. Among the strategic options attracting management and government interest are those of extending technological links with foreign manufacturers.

The process of internationalisation of the UK machine tool industry is not a new phenomenon. In a relatively open economy such as the UK, it has long been recognised that the national "technological state-of-the-art" is a function of indigenous research, design and development and imported technology. Any restructuring of the industry and repositioning of individual companies must start from the situation of foreign ownership of manufacturing capacity already accounting for an estimated 40 percent of sales by UK manufacturers, and additionally, a number of inward licensing agreements and other collaborative arrangements already in operation.

1.2 UK GOVERNMENT RESPONSE

Central features of the approach to industrial policy pursued by the Conservative Government immediately after 1979 were to promote: (a) the awareness and adoption of 'key facilitating technologies', of which advanced manufacturing systems was one, and (b) to offer financial support for approved projects in individual companies. Emphasis was placed on the autonomy of individual companies and ways of assisting them to respond to international competition. No formal policy document emerged at that time. The general direction had to be interpreted from statements by ministers and the various schemes implemented by the Department of Industry. Indeed, it was during the embryonic stage of this research that the Government's attitude towards sectoral policies and innovation unfolded, initially showing a marked reluctance to extend intervention beyond that of disseminator of information and provider of selective financial support. This was to some extent reflected in the statement of Michael Marshall (1981), Under Secretary at the Department of Industry, who said:

> 'Firms are responsible for identifying projects .... they provide most of the money to demonstrate their belief in the value of the work. They are responsible for the exploitation of the results

.... primary responsibility must be with the industry itself. It is an illusion to believe that their responsibility can be assumed by governments'.

Subsequent statements by ministers have consistently shunned the notion of sectoral policies and reinforced the view that individual businesses should be left to make decisions about deployment of their resources. While selective financial support for advanced manufacturing technology has been forthcoming to industry in general, Kenneth Baker (1983), then Minister of State for Industry and Information Technology, said that the machine tool industry was not a priority area. He went on to assert that every Government since the War had announced a strategy for the British machine tool industry and none had worked.

One of the first comprehensive statements of Government thinking was published by the Department of Industry (later Trade & Industry) in a pamphlet entitled: "Strategic Aims" (1983). This outlined the Department's central aim of achieving: 'a profitable, competitive and adaptive productive sector in the UK'. This was to be achieved by promoting: (a) a climate for UK industry as conducive to enterprise as that in any other industrialised country, (b) industrial efficiency through the selective use of the powers of government to achieve international competitiveness, and (c) opportunities for innovation, with technology available and applied on the scale necessary to ensure UK competitiveness.

Under the headings "Efficiency" and "Innovation" there were three elements of direct relevance to the themes developed in this research:

Efficiency (para. 2.4) highlighted 'inward investment and collaboration with foreign companies yielding competitive advantage to the UK ....'

Innovation (para. 3.1) referred to 'the scale and nature of research effort and inward technology transfer geared to UK industrial needs ....'

Innovation (para. 3.3) covered 'the awareness and rapid adoption of key technologies to maintain competitiveness'.

The foregoing statements are based on assumptions about declining UK competitiveness, technological deficiency and the superiority of foreign manufacturers. Implicit in this prescription is the perceived need for changes in the structure of industry and managerial practices and how they should be made. This is a much more "structurally-orientated" form of intervention than the "arms length" approach of 1980/81.

For over a century the traditional source of foreign machine tool technology has been the USA and this continues to be so across a wide front. The ascendency of Japan is a relatively recent phenomenon and as far as imports are concerned, these tend to be focussed on computer numerically controlled (CNC) lathes and machining centres. Government and industry attention has therefore turned to Japanese manufacturers, resulting in a "voluntary" restraint on imports and the encouragement of inward direct investment and collaboration. At the time of writing, one leading Japanese manufacturer, Yamazaki Machinery, had commissioned a £35m plant in the UK and several inward licence agreements and joint ventures had been signed between Japanese and UK manufacturers. The Yamazaki investment received a £5.2m grant from the Government and was described by Mr Norman Lamont (1984), Minister of State for Industry, as: '.... a showpiece factory at the forefront of advanced manufacturing technology'. Similar encouraging signs were evident in the Department of Industry's submission to the House of Commons Committee on Industry and Trade (1983) which highlighted examples of robot licence deals with Japanese manufacturers as:

> '.... an effective way to build up the UK's robot capacity as quickly as possible without wasting effort and resources on duplication of technical progress made elsewhere'.

The arguments in favour of attracting further foreign direct investment and inward licensing to British manufacturing industries typically hinge on: (a) the potential for short and long term job creation, (b) substitution of imports and the generation of exports, (c) stimulation of competition and revitalisation of indigenous manufacturers, and (d) acceleration of the flow of incoming technological and managerial know-how, which it is hoped will diffuse throughout the economy. Clearly, this is in the sphere of national political, economic and industrial policy, and extending beyond the mere increase of fixed capital formation. Moreover, it should be noted that although such inward investment policies tend to be associated with the Conservative Government, post-1979, they are not unlike the policies put forward by the Labour party both in government and in opposition. It was the Labour Government under James Callaghan, for example, which set up the Invest in Britain Bureau (IBB) to promote inward investment and this was retained after the general election of 1979.

1.3 THE COMPATIBILITY OF GOVERNMENT AND COMPANY POLICY

Throughout the five-year period of this study, research has focussed primarily on technology strategy and technology transfer at the level of individual business units. That Government policy evolved partially along similar lines not only reinforced the timeliness of the work but also heightened awareness among executives of foreign sources of technology.

Since the Government has had no specific policy for the machine tool industry per se, some of the initiatives outlined earlier have been variously criticised as a 'shotgun' approach to declining competitiveness, throwing money at 'technological fix' solutions and 'capitulation to foreign competition'. Such generalisations, however, by both Government and critics alike, say little about the nature of the competitive and technological challenges facing machine tool manufacturing companies, their receptivity to particular strategic options and managerial constraints on adjustment.

The machine tool industry exhibits low overall concentration and its products are highly diverse. It is also a highly cyclical industry. This means that it is unlikely that any single machine tool producing nation or company would wish to pursue developments on all fronts and specialisation based solely on the home market is of questionable viability. Thus business strategies must be framed in an international context and the timing of technological developments becomes a critical factor. It is only by examining strategic behaviour at the micro-level that insights may be gained into which technological options are likely to be the most effective and under what set of circumstances. Such research reveals whether the fundamental problems are technological or managerial, or both; and also provides a valuable perspective on the efficacy of Government policy.

The focus on technology strategy and international technology transfer implies neither technological determinism nor any preoccupation with the minutia of machine tool technology. No attempt has been made to impute success/failure to technological factors alone. Rather, while technology is regarded as making its own distinctive contribution to international competitiveness, this cannot be understood unless it is placed in the wider context in which business decisions are made.

2. A CRITICAL ANALYSIS OF THE LITERATURE

2.1 CORPORATE/BUSINESS POLICY AND STRATEGIC MANAGEMENT

2.11 Corporate/Business Policy

The early writers on policy (Ansoff, 1965; Learned et al, 1965; Andrews, 1971) and management philosophy and practice (Barnard, 1938; Drucker, 1954, 1968, 1974) adopted a prescriptive approach which was intended for a general audience of business school students and practising top executives. Their influential work centred on the analytical content of strategic decision-making embodied in the sequence of steps required to achieve desired managerial outcomes.

Ansoff (1965) is worthy of special mention in this critical review, mainly for his four 'components' of strategy which have entered the language of business strategy: product-market scope, the growth vector, competitive advantage and the concept of synergy. He offered these to help sharpen the firm's search for, and evaluation of, opportunities. In the critical selection of competitive advantage, straightforward steps were said to be taken but 'really successful results require uncommon skills in anticipating trends in markets and technology'. Technology per se was identified by Ansoff as a factor in the growth vector and appeared in his checklists to aid industry analysis and the appraisal of competitive/competence profiles.

Andrews (1971, p60) makes the profound statement that ....'technological developments are not only the fastest unfolding but the most far-reaching in extending or contracting opportunities for an established company'. And in a similar vein, Drucker's prolific writing frequently refers to 'technical change', 'technical aspects of work' and 'technology assessment'. But in seeking generality, there has been a tendency to understate technological and international factors under the broad umbrella of "business environment". This is not to denigrate the pioneering work of Ansoff, Andrews, Drucker and others, for they have stimulated strategic thinking and made valuable contributions towards a more ordered approach to business management. Intuition and common-sense observation tell us that they are close to reality and, indeed, many of their arguments have re-appeared in modified form in the work of later writers.

North American experience dominated the early literature. There continues to be a stream of publications from the previously mentioned writers and others (Harvey, 1982; Glueck & Jaunch, 1984; David, 1987), along with parallel works on corporate planning (King & Cleland, 1978, 1987; Lorange, 1980; Grant & King, 1982). A much-needed UK orientation towards business policy has been provided by Thomas (1977), Johnson & Scholes (1984), Howe (1986), Bowman & Asch (1987) and Luffman et al (1987); and on corporate planning by writers such as Hussey (1979, 1982), Argenti (1974, 1980), Higgins (1980) and Scholes & Klemm (1987). Some writers describe their personal experiences and refer to examples or case studies, while others draw on empirical research to enrich and support their various points.

Thomas, for example, follows a broadly based approach to business policy, defining it as the study of the nature and process of choice. His belief in the influence of socio-political forces in shaping decision-making behaviour is evident throughout, and he makes the important point that to study the nature of choices independently of the process of decision and the decision-takers is impossible in the real world. Thomas briefly considers technology in the context of organisation structure and managerial behaviour, and discusses technology transfer in two useful chapters covering policy options arising from product markets and international operations.

Johnson & Scholes and Bowman & Asch present a more structured approach, typical of a teaching book. They treat technology in socio-technical terms and, like Thomas, carefully build in personal values and power structures into their analytical framework. Johnson & Scholes make passing mention of franchising and licensing as 'joint development' options but disappointingly, apart from briefly discussing the multinational company as an organisation type, international business is conspicuously absent. As a general observation across the business policy literature, it seems that writers have neglected the technological dimension and have been slow to integrate the international dimension, leaving the latter open to separate treatment by economists.

2.12 Strategic Management

With the change in business environment from growth and relative stability associated with the 1950's and 60's to the turbulent conditions of the 1970's and into the 1980's, perspectives on business strategy have widened. This is particularly noticeable in the writing of Ansoff, who extended his narrow concept of product-market strategy to consider the multidimensional nature of strategic problems within a new paradigm of "strategic management", first articulated in Ansoff, Declerck & Hayes (1976).

Initially, strategic management appeared to offer little more than merely integrating some of the established concepts and techniques of business management; or possibly, due to Ansoff's rational stance, representing an emerging branch of operational research or management science. Gradually, however, as Ansoff elaborated on the organisation-environment link through "strategic issue management" (1980) and attempted to deal with the impact of technology (1984, 1987) it became clear that he was redefining the role of general management in a systems view of external change and internal adjustment :

> 'Strategic management is a systematic approach to a major and increasingly important responsibility of general management: to position and relate the firm to its environment in a way which will assure its continued success and make it secure from surprises.' (Ansoff (1984, pxv).

Ansoff (1980,p133) defined a strategic issue as ....'a forthcoming development, either inside or outside of the organisation, which is likely to have an important impact on the ability of the enterprise to meet its objectives.' The overall purpose being to prevent strategic surprises by assigning responsibilities for surveillance of trends and to sense signals of impending change. Ansoff (1984), however, stopped well short of detailed consideration of industrial setting, preferring instead to examine 'technological turbulence' and 'technological capability' as generalised phenomena; noting that: 'the strategic success of firms is less sensitive to the specifics of a technology than to certain key technological variables which are common across the spectrum of technology-based industries'. Building on earlier work (Ansoff & Stewart,1967), the variables Ansoff (1984) identified were : (a) investment in research and development, (b) competitive positioning, (c) product dynamics, (d) technological dynamics and (e) competitive dynamics. He proposed a simple framework for assessing their intensity and priorities, which in practice amounts to a technical audit. This is consistent with his declared aim of providing guidelines for general managers.

Schendel & Hofer (1979) have also emphasised the integrative role of the general manager in their interpretation of strategic management as:

> '.... a process that deals with the entrepreneurial work of the organisation, with organisational renewal and growth, and more particularly, with developing and utilising the strategy which is to guide the organisation's operations.' (Schendel & Hofer, 1979, p11).

Responsibilities for the process of strategic management in Schendel & Hofer's terms are typically shared by all managers rather than being divided by level or function, highlighting the need to move away from the artificial separation of medium/long term strategy and day to day operations. A key task of general management in their model is to facilitate cross-functional and multi-level interaction and they advocate giving greater prominence to strategy implementation.

Notable among the growing number of publications on strategic management to have significant impact on current thinking are the outstanding contributions from Michael Porter on competitive strategy (1980) and competitive advantage (1985), and from Kenichi Ohmae on Japanese business strategy (1982) and global competition (1985).

Porter (1980) sets out a framework for analysing industries and competitors. His book has the virtue of being highly "readable", which has widened its acceptability among practitioners. Porter's approach is developed around the identification of five competitive forces which determine industry structure (buyer power, threat of substitution, supplier power, intensity of rivalry, and potential entrants) and three generic strategies (overall cost leadership, differentiation and focus) for creating a defendable position in the long run and outperforming competitors. Sustained commitment to one generic strategy is recommended as the primary target to avoid dilution of effort, although Porter concedes that a focus (segmentation) strategy may involve a low cost position, high differentiation or both. Failure to develop in at least one of the three directions is described as 'stuck in the middle'.

Considering the high number of citations of Porter's work in the literature on strategic management, empirical validation has been remarkably slow and several studies have produced contradictory evidence (Hambrick, 1983; Dess & Davis, 1984; White, 1986; Miller & Friesen, 1986a, 1986b). The intense debate generated by these studies initially centred on the relationship between market share and profitability to show whether pursuing one generic strategy or mixed strategies separates high performing companies from less successful competitors. Hambrick, for example, used the Profit Impact of Market Strategies (PIMS) database to examine producers of capital goods. Among his high performing firms he identified clusters of differentiators and clusters of cost leaders, but never both combined. In contrast, Miller & Friesen used the PIMS database to examine producers of consumer durables, finding that none reflected Porter's pure types. Their differentiators also employed low cost strategies, cost leaders employed significant elements of differentiation, and some focussers were also cost leaders.

The controversy surrounding these findings then shifted its focus. On the one hand, attempts to identify generic strategies were welcomed, especially the insights gained on factors underlying competitive postion in a given industry and the potential for changing combinations of strategies with industry evolution. On the other, there was a growing challenge to the robustness of market share effects on profitability using PIMS data (Rumelt & Wensley, 1980; Jacobson & Aaker, 1985), with attention later turning to other strategic variables such as product quality (Phillips et al, 1983; Jacobson & Aaker, 1987). There seems little doubt that Porter's work will spawn more empirical investigation of this kind.

Porter's second book (1985) examined sources of competitive advantage and how two basic types (cost leadership and differentiation) may be sustained to achieve long term competitiveness. He devoted a whole chapter to understanding technological aspects of competitive advantage and it is written in the style of an industrial economist with few clues to his earlier training in mechanical engineering. He neatly defined technology strategy as: 'a firm's approach to the development and use of technology' and then incorporated an explicit reference to external sources of technology:

> 'Technology strategy must include choices about what important technologies to invest in, whether to seek technological leadership in them, and when and how to licence technology'. (Porter 1985, p165).

Porter saw 'strategic alliances' and 'coalitions' as vehicles for coordinating and sharing technology development to broaden and enhance the scope of the firm's overall "value chain". His concept of the "value chain" involved disaggregation of activities underlying competitive advantage in order to understand cost behaviour and existing or potential sources of differentiation.

Omhae's (1982) work is useful for his "key factors for success" which distinguish winners and losers in an industry, and "degreees of freedom" surrounding a key factor. In essence, his dictum is simple - first grasp the whole picture, then assess the direction(s) in which resources should be concentrated and exploit them aggressively. If there is freedom surrounding a key factor, say a technological factor, then an attempt must be made to assess the direction of technological innovation presented by opportunities. Surprisingly, Ohmae's reference to the role of foreign technology is limited to Japanese companies borrowing Western technology through licensing arrangements so that technology would not become a bottleneck to their growth and the need to work hard at improvement to catch up with the foreign licensor. Very little amplification is forthcoming in his later book on global competition.

It is difficult to compare Ohmae's style of writing with contemporary Japanese authors because few have received similar acclaim in North America and Western Europe. Ohmae did not set out to write academic books and the results must be viewed in this light. The content is unmistakably McKinsey & Company in origin and many of the concepts are to be found elsewhere (see Morrison, 1971; Morrison & Lee, 1979). His choice of examples drawn from Japanese business, like those of "popular" writers on business excellence (e.g. Peters & Waterman, 1982), is informative but there is little to enlighten strategists in the majority of companies which are not leaders. If any further adverse criticism may be made of both Ohmae and Porter, it is that they over-emphasise large firms operating in oligopolistic markets and under-emphasise strategy implementation and complexity of the environment in which individual firms operate. Their prescriptions are deceptively simple.

Progress towards operationalisation of ideas about strategic management has been achieved by addressing the question: how can we compete effectively in a given business? It is at the level of individual business units that understanding of products, markets and technologies is required and academic writers have begun to re-examine the strategic contribution of their discipline or function in the quest for sources of differential advantage. This is most evident in the marketing literature where proximity of strategic management to the organisation-wide "marketing concept" has received scrutiny along with opportunities for securing and sustaining competitive advantage through market segmentation, positioning, product innovation etc. (Murray, 1979; Biggadike, 1981; Day & Wensley, 1983, 1988; Gardner & Thomas, 1983; Day, 1984, 1986). There appears to be similar scope for an empirical investigation of contributions from technology within the integrative framework of strategic management.

2.2 TOWARDS THE STRATEGIC MANAGEMENT OF TECHNOLOGY

2.21 A Technology Strategy Schema

The 1980's has seen numerous calls to incorporate technological issues into the overall business decision-making process (Kantrow, 1980; Frohman, 1982; Buffa, 1984; Eschenbach & Geistauts, 1988), ranging from the need to know technological strengths underlying business success and using them as a competitive weapon (Morton, 1983; Frohman, 1985), to inadequacies of educational programmes for those who will manage design and technology (Oakley, 1984; Crisp, 1984). The quality of these and other publications is variable and most do not go much beyond projection of the general message that technological capability requires top management attention.

One of the best articles to emerge is by Maidique & Patch (1982) who start off by giving a useful definition of technology policy as .... 'involving choices between alternative technologies, the criteria by which they are embodied into products and processes and the deployment of resources that will allow their successful implementation'. They envisage an overlap between technology policy and manufacturing policy and describe the latter as .... 'encompassing decisions regarding the location, scale and organisation of productive resources within the bounds of a given technology'.

Maidique & Patch (1982), along with McLeod (1969), Freeman (1974) and Kotler (1988) have refined earlier work on a schema of four technology strategies first put forward by Ansoff & Stewart (1967). These strategies, based on timing considerations, may be summarised as follows:

> Leadership - an offensive strategy requiring strong research, design and development capability due to proximity of the state-of-the-art.
>
> Fast Follower - a reactive, second-to-the-market strategy aimed at learning from the leader's mistakes and requiring a strong design and development effort.
>
> Late Follower - a strategy based on overall cost minimisation and manufacturing capability. Often referred to as a "me too" strategy.
>
> Niche Exploitation - a segmentation strategy emphasising specialisation and requiring skills in design and applications engineering.

Maidique & Patch regard the above strategies as neither mutually exclusive nor collectively exhaustive. Ansoff & Stewart suggest that most companies should adopt a blend according to the requirements of their different markets or product lines. In contrast, McLeod advises that success is most likely to come to divisions which choose one strategy and stick to it, adding the rider that a niche (segmentation) strategy based on applications engineering is so different from anything else that it should not be combined with other strategies. These arguments surrounding compatibility of strategies are similar to those raised by Porter (1980) in pursuing his three generic strategies.

The fundamental questions emanating from the work of these writers are: (a) what technologies should the company invest in and what are the timing requirements, (b) what mix of research, design and development is necessary and how should this be organised, and (c) what are the sources of technology and how might these be evaluated? Two major factors in arriving at answers to such questions and choosing a strategy are: knowing the stage of evolution of the technology life cycle (Ford & Ryan 1981, Foster, 1982, 1985; Lee & Nakicenovic, 1988) and proximity to the leading edge of technology. These have managerial and resource implications for all functions of the business.

Most writers have emphasised the inherent instability of working at the frontiers of technological knowledge. Casson (1987, p253), for example, reminds us that it is a feature of any frontier that the environment in which people operate is 'not properly mapped out or understood'. Leach (1971) makes the important point that leaders must continually strive to repeat the advances by which they have attained their position, while simultaneously being sensitive to threats caused by either competitive emulation of their efforts or a breakthrough on costs. Porter (1985, p183) suggests that leadership strategies are costly and can only be justified if the initial lead is translated into first-mover advantages, a factor endorsed by Day (1986, p101) who saw most of the benefits accruing to pioneers as derived from 'opportunities to define the rules of competition to their advantage'.

Follower strategies have the main aim of 'learning from the innovator's mistakes' (Maidique & Patch, 1982, p277). Some followers may wish to stay a reasonable distance behind the leader, whereas others may attempt a 'second-but-better' approach (Urban & Hauser, 1980, p20; Foxall, 1984, p61). According to Day (1986, p105), fast followers are faced with the critical decision of whether to imitate or try to leapfrog the pioneer, or to enter a previously untapped market. He suggests that the question of "how fast is fast" is answered by the length of the introductory period of the life cycle: 'The window for a fast follower may be open for only a few months for microprocessors but several years for new machining systems'. Timing is, therefore, crucial to success. Waiting too long, runs the risk of customers placing faith in the leaders' products and substantial inducements may be required in terms of product superiority and performance to switch to a second-comer (Foxall, 1984, p61). Late followers generally need to exploit some distinctive competence such as customer service or low cost over selected product lines (Biggadike, 1977; Kotler, 1988).

All the aforementioned writers agree that successful leadership strategies are associated with access to strong in-house research, design and development capability; whereas follower strategies require design and production expertise. They also appear to recognise that external sources of technology may be used to augment any of the four strategies by reducing cost and lead time. 'Willingness to take new knowledge on licence and enter joint ventures' was identified by Carter & Williams (1957) as one of the characteristics of a 'technically progressive firm', defined as a firm which ....'on a necessarily subjective judgement, is keeping within a reasonable distance of the best current practice in the application of science and technology'. To avoid lengthening lead times and erosion of overall competitive position, it is also necessary to maintain a 'critical mass' of effort (Ansoff & Stewart, 1967) or 'threshold' level of resources (Freeman, 1974). Assessment of the absolute level and quality of such resources and the way they are managed is said to be a highly judgmental exercise.

2.22 Redefinition of the Business in Technological Terms

Against a background of severe economic recession in the early 1980's and the increasing cost of product/process development, there has been a resurgence of interest in redefining businesses in terms of their technological resource base. This was stated in its most penetrating form by Gold (1980, p504):

> '.... many industrial managements might well consider beginning their long range planning with a definition of technological improvement objectives and then redefining marketing strategies and financial requirements in accordance with resulting planned changes in technological capabilities'.

Fortunately, though much of the recent literature has re-opened the polarised and often fruitless debate on "technology push" versus "market pull" (Baker et al, 1987; Shanklin & Ryans, 1987), some writers are seeking a more balanced approach. Abell (1980), for example, proposed a simple three-dimensional model of customer groups, customer functions (benefits) and alternative technologies. In essence, he has mixed outputs and inputs by taking Ansoff's product-market approach and adding a third dimension defining alternative product/process technologies. This is useful where there may be several ways to satisfy customer product requirements and the choice of manufacturing process technology, thereby allowing scope for differentiation. Abell warns of the danger that consideration solely of product-market strategy may mean ending up in a lot of unrelated technologies with leadership in none. Similar recognition of technological capability is evident in (a) Ansoff's (1984) attempt to segment the environment in terms of "strategic technology areas" as an aid to defining strategic posture and (b) Deirickx & Cool's (1988) suggestion that the firm can be viewed as both a bundle of resources and a bundle of markets which operate simultaneously to determine competitive advantage.

Pursuing this line further hinges on the exploitation of "distinctive competence" residing in the highly specific nature of technology and how it can be incorporated into market positioning strategy and overall business strategy.

2.23 Cost Leadership Through Acquiring Technology

An approach to competitive strategy popularised by the Boston Consulting Group (BCG) combines the experience curve with product portfolio analysis (Conley, 1970; Day, 1977, 1986). The interesting extension of the BCG model is that by acquiring cost-reducing technology, the manufacturer with a moderate market share may approach the cost position of the dominant share holder by shifting to a lower experience curve (Day, 1977; Porter, 1979). This principle is at the heart of the cost leadership, and when coupled with capacity optimisation and high volume market penetration strategies, it ultimately affects price competitiveness. Unfortunately, experience curves are dynamic and seldom as smooth as the textbooks show. The permanence of cost advantages may be quesionable. Technological "leapfrogging" down the experience curve is evident in industries such as microelectronics and it is often very difficult to identify the cost leader for any length of time. The situation is further exacerbated by the timing of new product innovations, shared costs across product lines, and how executives interpret the threats and opportunities of emerging technologies (Millman, 1983).

2.24 Matching Business and Technology Portfolios

Booz, Allen & Hamilton have developed techniques for analysing technology alternatives and priorities using separate business and technology portfolios (Harris et al, 1982; Pappas, 1984). The business portfolio is a two by two matrix showing market attractiveness against competitive position. To facilitate matching, a technology matrix is constructed of "technology importance" (the relative importance that a specific technology plays in a given business segment) against "relative technology position" (a measure of firm's investment in technology). Though there are sound reasons for wishing to assess technology position to ensure consistency of business and technology portfolios, the technique is difficult to operationalise with any precision. As with all techniques of this kind there are problems in defining market share, market growth rate and dealing with cyclicality; and the definition of "relative technology position" using such measures as number of patents, human technical resource strengths, product history and expenditures, is fraught with difficulty. It is interesting to note that one of the foremost writers on portfolio analysis, George Day (1986, p215), devotes only half a page to this particular technique, completely omitting the kind of rigorous critique that is the hallmark of his work. Correspondence with Professor Day revealed his scepticism regarding the identification of discrete technologies.

2.3 THE MANAGEMENT OF RESEARCH & DEVELOPMENT AND PRODUCT INNOVATION

2.31 The Narrow Perspective of R & D

A cursory review of the literature on research and development immediately reveals that this is a prolific source of reports and articles. Much of this work is interesting, particularly that on project management, but only a few publications provide more than a tenuous link with the themes of technology strategy and inward technology transfer. Nevertheless, perceptions about the importance of R & D expenditure form a powerful influence on managerial decision-making.

The preoccupation with R & D as a key factor in economic growth is epitomised in the econometric work of Edwin Mansfield et al at Wharton

School of the University of Pennsylvania. Mansfield (1968) and Romeo (1975) identified R & D intensity (annual R & D expenditure as a proportion of sales turnover) as a determinant of an industry's rate of diffusion of technological innovations, noting that the higher the intensity, the greater the readiness to adopt innovations and the more likely the industry is to be in a position to assimilate new technology. Unfortunately, single indicators lack sensitivity as measures of innovative activity and competitiveness. They tend to hide differences in national product mix, technological inputs from outside the sector, cyclicality of sales and lumpiness of investment. Attention must also be drawn to the hazards in formulating policy and making budget allocations based on measures which use a ratio of current investment in R & D or innovation to sales turnover generated from the fruits of earlier investments. Various economists have attempted to remedy the last point by using time series data and distributed lag models to seek correlations between growth and R & D expenditure, patent counts, licence royalties etc (see Scherer, 1965; Branch, 1982; Odagiri, 1983). These multi-sector studies are technique-bound and at such a high level of aggregation as to lose much of their explanatory power.

A welcome shift away from consideration of formal R & D towards the wider concept of investment in product innovation was made by Mansfield et al (1971) in their examination of the proportions of total innovation cost and time arising at various stages in the process. Their study of chemicals, electronics and machinery product groups is valuable because it shows the cumulative nature of cost and time and that the non-R & D activities are substantial in product innovation. Precise interpretation of their averages is hazardous due to difficulty in assessing the degree of overlap between stages in the innovation process and the large variation in previous experience of the sample companies in the relevant technological area. For machinery products, the prototype stage and design/construction of tooling and manufacturing facilities accounted for about two-thirds of total innovation costs and over three-quarters of the time elapsed. Mansfield et al suggest that there are cost/time trade-offs to be had if executives wish to take them up but they make no reference to further savings in cost and lead times by using external sources of technology.

Potentially the most useful research on "innovative activity" has been conducted by Pavitt (1980, 1982, 1985) who combined R & D expenditure with measures of patenting and manpower resources. International comparisons have well known problems but he has made the best interpretation of such data as is available. Patent counts alone leave a lot to be desired because they say nothing about the economic value of individual patents. When examined in the light of national shares of patents filed in other countries, clues begin to emerge on export competitiveness and international orientation. Similarly with counts which do not reveal the quality of human resources and the redeployment of skills. As Pavitt (1980, p47) noted, ...'the process of creating and incorporating technology is labour intensive' and there is inadequate recognition of the importance in mechanical engineering of ....'the growing need to be able to design and develop total systems within which particular machines operate'. Taken together, Pavitt concluded that the three measures indicate there has been a decline in innovative activity in the UK mechanical engineering sector since the late 1960's.

2.32 Empirical Studies of New Product Innovation

One of the best new product studies conducted during the 1970's was

Project SAPPHO by the Science Policy Research Unit (SPRU) at the University of Sussex (Freeman, 1974). This involved a comparative analysis of pairs of successful and unsuccessful innovations, and identified several factors which discriminate success from failure: (a) better understanding of user needs, (b) attention to marketing and operating in familiar markets, (c) efficient product development, (d) employment of external technological expertise, and (e) authority vested in the project leader.

Rothwell (1977) has compared the findings of Project SAPPHO with eight other studies, and concluded that despite the pluralistic nature of explanations, responsibility for the success or failure of innovations rests firmly in the hands of management. He found that in most of the studies there was a bias towards "radical" rather than "incremental" innovations, a tendency towards project execution variables to the relative neglect of project selection, and greater emphasis on endogenous factors than exogenous factors. Additionally, Rothwell noted that factors associated with success and/or failure are significantly different in different industry sectors and that these differences are as important as the cross-sectional points of similarity. He pointed to the danger of casting the net too widely and that in-depth sectoral studies would appear to yield the potentially most meaningful results.

Subsequent empirical research by SPRU (1981) has provided a database on more than 2000 significant innovations covering 30 sectors of UK industry. The findings are broadly corroborative of Project SAPPHO and other studies compared by Rothwell. An interesting possible direction for future research to emerge from the 1981 SPRU report was the need for better information on the use of foreign technology through formal licensing transactions and more informal methods such as personal contracts and copying through reverse engineering. Several years later, the same need for research on different forms of internationalisation and technology transfer was identified by Francis (1987, p2) in an Economics & Social Research Council report.

A valuable insight on the value of external sources of technology in speeding up the rate of innovation was provided by Gee (1978, 1979). He reported the results of a project commissioned by the US National Science Foundation which examined 500 significant (from the technological and socio-economic point of view) innovations originating from six countries over the two decades 1953-73. Despite the difficulties of defining end points, the "average innovation time period" was used as a convenient indicator of innovative performance on the justification that all the confluent factors which act to stimulate or impede the innovation process will be reflected in the innovation period.

Gee concluded that internally generated technology was the principal source for all firms, although there was a strong correlation between shorter innovation periods and higher dependence on external sources of technology. An international comparison showed that Japan exhibited the shortest average innovation period of 3.4 years, West Germany 5.2 years, the USA 7.4 years and the UK 7.7 years. Improved innovative performance and competitiveness was associated with a balance of external and internal sources of technology.

2.33 Managerial Perspectives

Traditional approaches to research and development as project-based activities or front-ended inputs to the product innovation process have shaped the treatment of innovation itself in the literature. Many of the publications on the management of innovation, industrial marketing and product management include multi-stage models describing the process to be one of taking an idea through a number of sequential stages to commercialisation (Twiss, 1980; Wind, 1982; Chisnall, 1985; Cooper, 1988). Invariably it is recognised that there are substantial overlaps, iterations and feedback loops; and various screening and review procedures to check cumulative cost/time projections and conformity with business objectives (Millman, 1986). These models resemble the analytical-rational approaches found in the literature on business policy and planning.

In one of the most cogent books on the management of innovation, Twiss (1980) has tackled inward licensing in a positive way, referring to it as 'buying the fruits of another company's R & D investment'. He opens his book by posing two strategic questions facing executives in industrial companies:

> Can objectives be achieved more economically by licensing another organisation's technology than by initiating an internal R & D project?
>
> Can the potential of licence agreements be realised without a strong in-house R & D capability? (Twiss, 1980, p2)

While noting that many companies are markedly reluctant to pursue an active licensing policy, he adopts a pragmatic approach to the familiar problem of limited resources:

> 'Even the largest companies cannot afford to examine all the technological alternatives or produce all the worthwhile innovations ... there is little gain from rediscovering what can be obtained from another source more cheaply'. (Twiss, 1980, p58)

Twiss offers no explanation for cautious approaches to inward licensing and has nothing to say about the integration and compatibility of licensed technology with existing systems. Most authors have treated these in a superficial way. Resistance to inward licensing is typically dismissed in a few sentences as fears of technical dependency and inhibition of in-house skills (Fielden, 1963), legal uncertainty (Cawthra, 1978), and lack of a strong enough coupling with the licensor (Robertson, 1969). Licensed products are assumed to enter the decision-making framework as opportunities ready to be assessed for profitability or techno-commercial fit (Berridge, 1977; Pessemeir, 1982).

One of the foremost researchers on technology management is Thomas Allen at Massachusetts Institute of Technology. Allen's early work (1966, 1972, 1977) clearly showed that the flow of technological information from group to group and from stage to stage in the innovation process is critically dependent on social interaction and that the possibility of communication between work groups is rapidly suppressed with increasing distance apart. To fulfill a communications need that the formal organisation is incapable of satisfying, Allen & Cohen (1969) noted the role of 'technological gatekeepers'. These boundary-spanning individuals were said to be found at lower levels of the organisation and provide a mechanism for the inward transfer of information. The more clearly defined the organisation boundary and dynamic the technology, the greater the 'communication impedance' and the need for gatekeepers (Allen et al, 1977; Allen et al, 1979). Correspondence with Professor Allen (May 1986) resulted in receipt of a number of unpublished MIT Sloan School of Management Working Papers. These described research which replicated the existence of technological gatekeepers and the dominance of personal contact in successful technology transfer in a range of organisation types.

Later, Allen et al (1983) extended their research on technology transfer across international frontiers by tracing 'sources of innovation-producing messages' that brought technology into small manufacturing companies in Ireland, Spain and Mexico. An important conclusion from their work was that domestic companies relied heavily on messages from overseas and sources in the same industry, and in particular, contact with foreign competitors. In contrast, foreign-owned subsidiaries obtained the greatest proportion of their technology from their parent company but were often constrained in exploiting external channels, resulting in 'stifling creativity and entrepreneurial behaviour'.

2.33 Inward Licensing and the Adoption of Innovations

After making the earlier point that much of the literature is of the rational-analytical type, it comes as no surprise to find similar models and checklists in the literature on inward licensing (Brazell, 1966; Marcy, 1979; Hamman & Mittag, 1985). This rationality of purpose and behaviour is implicit in Gee's (1981, p105) description of the early stages of inward licensing:

> 'The acquisition of technology developed by others being highly demand responsive means that decisions to do so usually are carefully weighed and reached only after extensive and comprehensive search and evaluation of candidate technologies for technical and economic appropriateness...'

The above statement is by one of the foremost practitioners of licensing at the US Naval Surface Weapons Centre at Maryland and may well indicate closer adherence to the normative model in military research establishments and other highly project-based organisations. Parallels are to be found in the logical flow models in the early literature on industrial/organisational buyer behaviour (Robinson, Faris & Wind, 1967). Subsequent models have encompassed receptiveness to new ideas and the influence of a host of contextual factors on pre-purchase behaviour, much of which has value in the study of inward licensing.

Licensing and joint ventures are negotiated transactions more akin to the interactive models of buying/selling (Hakansson, 1983; Hutt & Speh, 1984) and there are other useful concepts to borrow such as the dynamics of the "Decision-Making Unit" (Buzell et al, 1972). From the few empirical research studies on licensing, there is evidence of 'satisficing' during negotiation (Contractor, 1981), licensing as the result of 'ad hoc factors' rather than a rational examination of alternative strategies (Lowe & Crawford, 1983, p16), and the decision process influenced by 'casual encounter or even the personal peccadilloes of an executive' (Davies, 1977, p165).

The way in which internal and external pressures are perceived and evaluated by executives appears to be crucial to whether particular product/process technologies are adopted. Pertinent questions include:

(a) Are executives aware that foreign technology is available, and from whom?

(b) Is there unanimity at board level?

(c) Is the company risk-averse?

(d) Has executive attention been diverted to solving more urgent problems, perhaps of a non-technical nature?

(e) Is the company in strategic trouble and pursuing what Knight (1967, p485) called 'distress innovation'?

(f) What are the potential benefits of adoption and the penalties of non-adoption?

The purpose of this line of enquiry is captured succinctly by Gold et al (1980, p14):

> 'In order to provide more useful guidance for policy making by government agencies and industrial managements, research must provide fuller understanding about the bases on which those facing

> such decisions choose to adopt, reject or defer action; about why firms within a category of active prospects arrive at different decisions; and about the probable effect on such decisions of alternative future developments.'

Underlying the decision to pursue licence-based product and process innovation are complex socio-political processes. These involve resistance to external sources of technology captured in the so-called "not-invented-here" syndrome (Schon, 1967; Katz & Allen, 1982) and the tricky area of personal innovativeness (Rogers, 1962, 1983; Rogers & Shoemaker, 1971; Hage, 1980; Foxall, 1984).

The NIH syndrome is a well known, yet under-researched, aspect of receptivity to change. Schon describes resistance to change not as inertia, but a state of "dynamic conservatism" in which members of an organisation are actively striving for survival, stability and continuity against threats to their identity. Similarly, Katz & Allen in one of the few empirical investigations of the NIH syndrome, noted that the long tenure of R & D project groups reinforces the status quo and that individuals may come to rely more heavily on their own knowledge, views, experiences and capabilities, thereby reducing their attentiveness to outside sources of information and expertise.

No empirical research is thought to have been carried out specifically on the lingering effect of bad experiences on the NIH syndrome and receptivity to foreign technology. A 'negativity bias' has, however, been identified in cognitive processing (Kanouse & Hanson, 1972) and bad experiences are said to have greater persuasive impact than positive experiences (Wright, 1974; Mizerski, 1982; Richins, 1983).

Hage (1980) suggested that as people become exposed to different cultures, languages, social groups, and so on, the less they will resist radical change. Rogers (1983), mainly known for his work on the diffusion of innovations, referred to this external orientation as 'cosmopoliteness', which he found to be positively associated with innovativeness. Foxall (1984, p128), in turn, simply defined innovativeness as ....'the capacity and tendency to purchase new products and services'. In a useful review of the empirical research, Foxall noted that among other things, innovators exhibit greater internal and external social interaction, have positive attitudes to change and greater interest in the product area to which the innovation belongs.

Some of the recent expositions on "business excellence" have taken up these themes in the form of "international orientation". Senior managers have been urged to maintain a high natural curiosity about how things are done elsewhere, establish networks for the exchange of information and ideas, and to encourage business intelligence gathering through foreign travel (Goldsmith & Clutterbuck, 1987; Heller, 1987). These observations and empirical findings suggest that a study of inward technology transfer should at least explore the earlier background of key decision makers, their external orientation and contextual factors, in an attempt to assess the extent to which their behaviour strays from the normative model.

2.34 Product Design Management

A strong case for product designers making a more pro-active contribution to international competitiveness has been made in the literature (Roy et al, 1981; Rothwell et al, 1983; Kotler & Rath, 1984; Millman, 1986; Lorenz, 1986), but there are only a few publications covering design management (Topalian, 1980; Oakley, 1984; Heap, 1989). Emphasis is placed on the potency of design in achieving product through aesthetics, ergonomics, reliability and maintainability. Cost reductions have also been highlighted by urging careful attention to design for economic manufacture and assembly.

The Feilden Report (1963) was one of the first to recognise the change in international competition brought about by the rise of West Germany and Japan. Feilden's brief was primarily to recommend remedies for shortcomings in the training and professional status of engineering designers. He also drew attention to strong evidence of the :

> '....failure of particular sections of British engineering industry to keep abreast of foreign competitors in redesigning their products to take advantage of advances in technology'.

The Corfield Report (1979) centred on product design and ways of compensating for deficiencies against a much more serious background of declining competitiveness. Corfield amplified many of Feilden's earlier words and demonstrated the clear connection between good design (in the sense of design that facilitates production) and higher productivity. He also emphasised the need to be internationally-minded about standards and codes of practice and that:

> '....international links should be encouraged to ensure that the body of technology is fully representative of international expertise and not excessively nationalistic in its traits'.

In the hope of placing design responsibility on a par with other functions, Corfield and others (Height, 1986) have recommended separate design representation on boards of directors. This is likely to find limited support among engineering and technical directors who already see it as part of their role. There appears to be consensus of opinion that the design activity should be raised in visibility, yet conflicting ideas abound on how this should be achieved. A factor underlying this concern is the shift from labour-intensity towards capital-intensity, particularly in draughting tasks, with the advent of computer aided design (CAD) systems. CAD is forcing design-related expenditure decisions to a higher level in the organisation, but while the costs may be associated with the design function, the benefits are far-reaching and not easy to measure.

2.4 MANUFACTURING POLICY AND PRODUCTION/OPERATIONS MANAGEMENT

2.41 Internal Barriers to Achieving Competitive Advantage Through Manufacturing

The debate relating to the strategic role for manufacturing and production has highlighted two issues of crucial concern: (a) a cluster of controversial developments of an "internal" nature, ranging from perceptions about the relative status of the manufacturing function, to its input to business strategy formulation and the need to encourage linkages between the strategic level and operations, and (b) changes in the external competitive environment which demand new responses from managers and engineers to the matching of product design and manufacturing process technology to achieve systems benefits.

An early influential article which captured the essence of the internal problem was that by Skinner (1969) who postulated manufacturing as 'the missing link' in company success. He saw manufacturing as traditionally carrying low status and emphasising the achievement of high productivity and low cost. Top management was said to unknowingly delegate a large proportion of policy decisions to lower levels in the manufacturing area, thereby binding the company to a non-competitive posture which may take years to turn around. Later, Skinner (1978) offered the concept of improving 'infrastructure' to achieve competitive advantage, involving the matching of technology to human components in a complex social system of people, administrative systems and policies. Implicit in this concept was the need to move down from top management levels to lower levels at which decisions are made and in the area of operations where the implications of technology are felt.

Skinner's dictum has since encouraged others to elaborate on the status of manufacturing and consistency among multi-levels of decision-making. Hill (1980, 1983), for example, contends that manufacturing managers see their role as "responding". They join the corporate debate late and seldom expose the manufacturing implications and production perspectives to others. Manufacturing departments, he asserts, are typically asked to comment on the feasibility of a plan already formulated. This inward-looking, short-term, orientation was a prominent behavioural characteristic emerging from an empirical study of production managers by Buckingham & Lawrence (1985):

> 'These managers are keeping a creaking system going but they are not on the whole a force for regeneration .... questions of planning, systems and policy are neglected while those who understand how to sort out immediate problems get on and sort them. But this will not stop the same problems arising tomorrow'.

Further support for this view is offered by Wheelwright (1985) who suggests that a static view of manufacturing keeps it in a responsive mode and process evaluation is seen as an after-thought. According to Wheelwright, top management attention devoted to activities normally thought of as short-term and situation-specific is a factor underlying Japanese business success. He saw this 'strategic operations policy' as sadly neglected in Western industrial companies, leaving hands-on experience untapped in strategy formulation.

The matching of product and process technology has always been a central issue in achieving competitive advantage because of acceptance that as products and markets mature, a "dominant design" emerges and the emphasis shifts from product innovation to process innovation (Abernathy & Utterback, 1975, 1978). Commenting on the changing competitive situation in the 1980's, Williams (1983) noted ....'a shift from the investment characteristics of product technology to those of process technology as the primary focus of competition'. This generates a number of questions about changing power structures and organisational rigidity with increasing capital intensity, and the need for strong linkages between product design, manufacture and assembly.

2.42 Coping with the Introduction of New Manufacturing Technology

Machine tool manufacturers are facing the same set of decisions concerning computer integrated manufacture in their own plants as their customers. As they progress towards machining cells and flexible manufacturing systems, the notion of economies of scale is replaced by 'economies of scope', bringing the cost of small batch production closer to that of high volume production (Panzer & Willig, 1977; Jelinek & Goldhar, 1983, 1985). Thus computer integration offers the opportunity to tackle the age old trade-offs between "efficiency and flexibility" (Katz & Allen, 1985; Easton & Rothschild, 1986; De Meyer et al, 1987).

There is general agreement in the literature that the transition to computer integration is problematic. Structural reasons lock companies into outdated technologies (Hayes & Abernathy, 1980) and the divisability of machine tool technology has meant a better chance of survival of older techniques (Ray, 1984). Moreover, to exploit the full systems potential of computer integrated manufacture, it must be accompanied by the implementation of just-in-time philosophies and materials requirements planning systems, which rely heavily on a well developed internal and external infrastructure for their smooth running. As Voss (1985) pointed out: the new manufacturing technologies represent the first radical change in process technology for some time. Due to greater flexibility and responsiveness, the benefits extend beyond productivity and they also involve a new discipline, computer software, that is not embedded into traditional manufacturing and engineering operations. Such changes have long term consequences for career hierarchies (Lee, 1985) and have prompted calls to abandon or radically revise organisation structures (Bhattacharyya, 1985; Ingersoll, 1987; Hayes & Jaikumar, 1988).

Organisational integration has been highlighted as one of the key manufacturing issues in the 1980's. Indeed, "Towards Integration" was the theme of a Department of Trade & Industry (1987) initiative aimed at increasing managerial awareness of the need for cross-functional integration and providing assistance with feasibility and implementation studies. Unfortunately, the debate has been dominated by "back-to-basics" approaches which, no matter how well-intentioned, concentrate more on "what to do" than "how to do it" (Daughters, 1986; Heard, 1987; Ingersoll, 1987).

Among the management consultants, Ingersoll's (1987) attack on 'traditions' is a case in point. They recommend abandoning obsolete functional organisation structures, dismantling 'brick walls' between functions, and re-organising around ....'the mainstream of your business (i.e. people, products, markets) or even profit'. This resembles earlier ideas on the structural configuration of 'adhocracy' (Toffler, 1970, 1985; Mintzberg, 1978) but with little advice on how to bring about 'mutual adjustment' as the integrative mechanism in a complex environment. Managing discontinuities involving substantial attitudinal and behavioural changes requires more than the 'courage' or 're-writing the rules' that Ingersoll suggest. The gap between proponents of radical change and those seeking more incremental approaches is poorly breached in the manufacturing literature, leaving practitioners who might wish to pursue the middle ground in a difficult position. This issue is important and will be raised again later in the context of organisational development.

2.43 The Assimilation of Foreign Manufacturing Technology

The problems exposed in the previous discussion provide the backdrop for the inward transfer and assimilation of foreign manufacturing technology. Many of the aforementioned problems may arise irrespective of the source of technology. In the case of inward technology transfer, however, additional difficulties reside in the firm-specific nature of process know-how and how cultural differences affect supplier/recipient relationships.

The impact of foreign technology depends on whether assimilation takes place in a greenfield plant or in the potentially more disruptive case of assimilation into existing operations. Replication of the technology suppliers' systems may be possible when setting up greenfield operations or when the transfer is intra-company and internal procedures are common (Behrman & Wallender, 1976). But in most cases, earlier changes of ownership, varying degrees of autonomy and presence in different markets precludes such close and continuous matching of systems. A more likely situation is that of technology suppliers being further along the product/process life cycle than the recipient, producing larger volumes and using different (incompatible) equipment. This is often the case with unrelated suppliers and recipients, such as in joint ventures and licensing, where extensive adaptation of the incoming technology may be necessary. These issues are poorly covered in the literature on technology transfer and absent from the managerial literature on manufacturing/production operations.

To ease assimilation, technology suppliers attempt to: (a) "embody" their technology via the import of capital equipment, knock-down kits and components, or (b) "codify" it in the form of engineering drawings, software, parts lists, manuals, process schedules etc. Managerial and other know-how, less amenable to codification normally involves initial training and continuous interaction. Existence of these practices is noted in the literature (Vaitsos, 1974; Kerr, 1981), especially from the legal perspective (Cornish, 1981; Fowlston, 1984; Hearn, 1986,1987). Again, detailed consideration of the implications for manufacturing has received little attention.

Teece (1976), an industrial economist, identified four main determinants of the resource cost of transferring and assimilating 'unembodied' know-how: (a) the degree of codification, (b) its proximity to the state-of-the-art, (c) accumulated managerial and technical skills of the recipient, and (d) previous experience of manufacturing products in the same or related product groups. Teece found that the costs were both substantial and highly variable. Lower costs were associated with more experienced companies. This tends to suggest the importance of a learning curve in technology transfer and provides further support for the notion of maintaining a critical mass of skills.

2.5 ORGANISATIONAL DESIGN AND BEHAVIOUR

2.51 Strategy, Structure and Power Distributions

The literature on organisations complements and often pre-dates that on business strategy. Of the many different conceptual and empirical approaches pursued by writers, there are important linkages to be made which underpin any study of technology strategy development. The first point of reference is the seminal work of Chandler (1962) who examined the impact of strategy on organisation structure, showing that a change in strategy is likely to eventually result in a change in structure. This spawned a number of studies aimed at either replicating Chandler's thesis or extending it to cover other variables. These included: (a) Fouraker & Stopford's (1968) study showing that structure constrains strategy, (b) Child's (1972) "strategic choice" approach, indicating that management decisions influence the relationship an organisation has with its environment, (c) Rumelt's (1974) study of performance against different degrees of diversification, and (d) Franko's (1974) findings that competition has a moderating effect on strategy/structure relationships, with competitive pressures leading to deterioration in performance and requiring structural adjustments to restore profitability.

After reviewing these and several other contributions, Galbraith & Nathanson (1979) concluded that although there is substantial support for Chandler's thesis, subsequent empirical research has introduced modifications and the causal sequence is increasingly difficult to establish. They felt it was less important to know whether strategy causes structure (or vice versa) and more useful to ensure they are eventually brought in line. Complete explanations were said by Galbraith & Nathanson (1970, p283) to lie in multiple perspectives, giving ....'an adequate understanding of market conditions performance and the relative power of dominant managers, coupled with an historical perspective of individual firms'.

Widening the strategy/structure debate to include the sources and distribution of power within organisations is important because it raises the issue of power as a property of social relationships, the formal division of labour and interdependency (Perrow, 1970; Hickson et al, 1971; Hinings et al, 1974; Pfeffer, 1981). According to these writers, power is distributed internally among individuals and groups mainly depending on: (a) their position in the hierarchy, (b) their ability to cope with environmental uncertainty, (c) the availability of alternative sources of expertise, and (d) the degree to which their activities are interlinked. These provide the basis on which power may be exercised to influence strategy and cannot be separated from associated political behaviour and questions of legitimacy. The methodological problems of studying and operationalising the concept of power were sharply articulated by March (1981, p216):

> 'It tends to become a tautological summary of the (large) residual variance in studies of collective choice; it confounds a variety of quite different behavioural mechanisms; it has no consistent measure; and the models that underlie it seem often to be either clearly wrong or impossible to test'.

Despite the dangers of masking ignorance implied in March's statement, it is generally recognised that power structures may be diagnosed, albeit crudely, by examining various indicators, such as status symbols, resource allocations, rituals, rewards and representation on key committees (Pfeffer, 1981; Johnson, 1987; Harrison, 1987).

The implications of power distributions for strategy development and organisation structure design arise from the imbalance that may occur if one subunit is allowed to dominate for any length of time. As Maidique & Hayes (1984, p22) point out: 'strategies that appear to elevate one function above the others, either in presige or rewards, can poison the atmosphere for collaboration and cooperation'. 'Nothing', according to Shanklin & Ryans (1984, p35), 'shapes the overall direction of the organisation more than this (functional) pecking order'. The challenge facing managers is neatly summed up by Ansoff (1987, p30) as the need for 'strategic orientation': a balance of functional influences, power centre shifts from the dominant function to general management, and optimisation of the firm's investment in the market place.

2.52 Contingency Approaches

Attempts to pay greater attention to the way in which business organisations interact with their environment are at the heart of open systems or contingency theory. This has evolved partly in response to growing dissatisfaction with normative models which assume universal transferability of strategy and managerial skills from one environmental setting to another. Among the early writers encouraging the adoption of contingency approaches were Burns & Stalker, Woodward and Lawrence & Lorsch.

Burns & Stalker (1961) posited "organic" and "mechanistic" structural styles as appropriate responses to relatively dynamic and stable environments respectively. Woodward (1965, 1970) identified manufacturing technology as a primary determinant of organisational form, her studies concentrating on the coordination and control imposed by technology. Organisations were grouped according to their mode of production in ascending order of technological complexity: small batch, large batch, and continuous/automated mass production. Successful firms in the first and last production modes tended to follow more permissive organisation styles and in the second mode an hierarchical style. Organisation researchers appear to agree with Woodward that technology is an important variable but there is considerable debate concerning the primacy of organisation size (Pugh et al, 1969; Hickson et al, 1969), technological interdependency and 'mutual adjustment' (Thompson, 1967), and information processing requirements (Galbraith & Schoemaker, 1978).

Lawrence & Lorsch (1967a, 1967b) focussed on the relationship between environmental uncertainty and organisation structure, observing that environmental change affects the sub-systems of an organistion in different ways. Functional differentiation was seen by Lawrence & Lorsch as necessary to deal with different sub-environments and the need to integrate functional interdependencies was brought about by the key competitive requirements of the industry. Most definitions of integration may be traced back to Lawrence & Lorsch (1967, p11) as :'the quality of the state of collaboration that exists among departments that are required to achieve unity of effort by the demands of the environment'. Subsequently, researchers have tended to place more emphasis on the use of integrative devices and liaison roles to achieve collaboration than such issues as political accommodation and legitimacy.

The main criticism of contingency theory is levelled at the extreme case of highly "situational" perspectives which assert that performance and behaviour depend on the set of circumstances at a particular point in time (Mockler, 1971; Lufthans & Stewart, 1977). Miles & Snow (1978) suggest that the notion of "every situation is different" becomes an atheoretical point of view, providing even less guidance than the universal assumption that "every situation is the same". They criticised contingency approaches for the emphasis on deterministic views of environment, rather than how managerial choice affects the direction, shape and actions of the organisation; and for their bias towards individual differences rather than similarities.

Miles & Snow were principally concerned with modelling organisational adaptation and proposed a typology of adaptive behaviour. An essential element of their model is the identification of three inter-related 'problems' which they classified as entrepreneurial, engineering and administrative. The engineering problem was characterised mainly by choice among technologies and represents one of the few attempts to build technology into a conceptual framework for the understanding of adaptation to change. Miles & Snow's research is typical of the neo-contingency approach suggested by Kast & Rosenzweig (1973), who saw this as occupying the middle ground between the view that there are universal principles of organisation and management, and the view that each situation must be analysed separately.

2.53 Socio-Political Perspectives

Consolidating and extending the aforementioned contingency studies is a group of researchers dedicated to understanding the "process" of strategy development. Their studies largely grew out of the early work on 'bounded rationality' and 'satisficing' (Simon, 1957; March & Simon, 1958) and polictical processes (Cyert & March, 1963). Since then, empirical studies have included: (a) further investigation of political and cultural processes (Pettigrew, 1973, 1985; Fahey, 1981; Johnson, 1987), (b) combined analytical and political processes embodied in 'logical incrementalism' (Quinn, 1980), (c) unstructured decisions (Soelberg, 1967; Mintzberg et al, 1976; Mitroff & Emshoff, 1979; Mitroff, 1980), and (d) the distinction between "intended" and "realised" strategy (Mintzberg, 1979).

Most of the recent studies of social systems in business contexts draw to some extent on the writing and research of the last-named author, Henry Mintzberg. He made two important observations on the process of strategy development: (a) that strategy should be viewed as a mediating force between the organisation and its environment: and (b) that strategy formulation is not necessarily the prerogative of top management and may originate in other (lower) levels of the organisation. Specifically, Mintzberg (1979, p25) states:

> 'Strategy formulation involves the interpretation of the environment and the development of consistent patterns in streams of organisational decisions to deal with it'.
>
> '.... the process of strategy formulation is not as cut and dried as all that: for one thing, the other parts of the organisation, in certain cases even the operating core, can play an active role in formulating strategy, strategies sometimes form themselves, almost inadvertantly, as managers respond to the pressures of the environment, decision by decision'.

The process school of researchers is also responsible for pointing out that it is crucial to understand the problem-sensing and diagnostic stages leading up to the definition of strategic problems as these largely determine subsequent courses of action (Gilmore, 1973; Mintzberg, 1976; Pettigrew, 1985). One of the best attempts to model strategic problem formulation among top managers was by Lyles (1981), who proposed a two-stage model which commences with individual processes and then evolves into organisational processes. It is attractive because it recognises that: (a) attitudes, values, cognitive styles and job characteristics affect the way individuals conceptualise strategic problems; and (b) political behaviour among sub-units shapes definition of the nature of strategic problems, perceptions of their causes and significance for the organisation.

To paraphrase Lyles, the first stage of her model involves individual executives becoming aware that a potential problem is emerging - a sense of unease that something is wrong. This occurs before supporting data is available and is followed by an incubation period during which diverse information is pieced together. When sufficient information has accumulated and the problem can no longer be ignored, a "triggering point" is reached and the process moves into the second, organisational stage, precipitating a more formal information-gathering exercise and wider discussion among top managers. She notes that recycling may take place between the individual and organisational stage as more information becomes available and there may be soliciting of support for particular interpretations prior to problem definition. Alternatively, no definition may be attained or the problem reduced in priority, or ignored. Such behaviour is likely to feature in the definition of technological deficiencies and receptivity to foreign technology. As Child (1984, p264) succinctly put it: 'the introduction of new technology into organisations is a political process around a political issue'.

2.54 Organisational Development

A major theme throughout the literature on organisational development is that of "planned change to improve organisational effectiveness". Emphasis in the early literature was placed on the need for interventions which involved (a) "unfreezing" organisations, (b) attempting to change attitudes and obstructive behaviour of individuals and groups, and (c) "refreezing" once the desired relearning was thought to have been achieved (Lewin, 1947; Lippitt et al, 1958; French & Bell, 1973). This rather mechanistic approach was eagerly adopted by consultants in the organisation development field and has had considerable influence among others concerned with the introduction of new technology. It is now giving way to more subtle, yet penetrating, approaches which view organisational development as a process of continuous change, requiring deeper understanding of organisational learning (Argyris & Schon, 1978; Fiol & Lyles, 1985; Garratt, 1987) and the relationships, values and beliefs comprising organisational culture

(Schein, 1983, 1985; Marshall & McLean, 1985).

Hrebiniak & Joyce (1984) retained the notion of "planned change" and proposed an integrative framework for managerial intervention based on the magnitude of strategic problems and their implementation time horizon. Styles of intervention in their framework ranged from evolutionary (small strategic problem, long time horizon) to complex (large strategic problem, short time horizon) with a corresponding increase in the difficulties of formal planning, coordination and integration. Hrebiniak & Joyce ask the crucial question: how long will the organisation stay in business if it continues its activities as it is today? If the answer is several years, then they suggest that sequential interventions are feasible. If the answer is a few months, then complex concurrent interventions must be made.

Emerging views of organisational learning and organisational culture fit comfortably in Hrebiniak & Joyce's framework and throw light on why radical change is so difficult to achieve. Marshall & McLean (1985, p6), for example, suggest that two orders of change should be considered: (a) 'first order' change involving adjustments to ways of working, with the ground rules remaining essentially unaltered, and (b) 'second order' change where the basic assumptions change requiring modification of attitudes and behaviour. While observing that most managers attempting the latter actually achieve the former, Marshall & McLean go on to criticise some of the harsher interpretations of obstructive behaviour. They argue that forces for stability in an organisation are not necessarily obstacles to change but are legitimate needs which require attention and can become sound platforms for eventual change. Earlier work by Watzlawick et al (1974) on problem formulation offers a similar approach in which they note that little true change can occur because people become stuck in routine behaviour and restrict their frame of reference for handling problems. Thus, breaking existing patterns of thinking to effect second order change requires interventions which challenge the "world view" of managers and result in what Kuhn (1970) referred to as a 'paradigm revolution'.

The concept of an 'organisational paradigm' (Sheldon, 1980) is important because new knowledge is unlikely to be accepted if it conflicts greatly with the prevailing paradigm (Duncan & Weiss, 1972, p95). In the context of technology strategy development, this was usefully extended by Dosi (1982) who proposed a model based on 'technological paradigms' and 'technological trajectories' as a way of characterising technological change. In essence, he argued that continuous (incremental) technological change relates to progress along a trajectory within the prevailing paradigm, while discontinuous (radical) change is associated with shifting to a new paradigm. Technological paradigms, according to Dosi, also have a powerful 'exclusion effect' which may induce blindness with respect to other technological possibilities.

Staw & Ross (1978) observed that the longer individuals have participated in, and become responsible for, a set of strategies; the stronger their attachment to them, even though they may eventually become outdated. As Child et al (1977, p104) point out, these individuals ....'assign priorities to goals and declare constraints to be movable or rigid, by filtering information and applying analytical models or templates that worked in the past and are therefore widely accepted'. This reliance on conventional wisdom later found expression in Rumelt's (1979) 'strategic frame' for an industry and Spender's (1980) 'recipes'.

Three main conditions for change were identified by Tofler (1982, p2): (a) enormous external pressures, (b) people inside the organisation who are strongly dissatisfied with the existing order, and (c) the existence of a coherent alternative embodied in a plan, a model, or a vision. Given the role of the chief executive and board of directors as the 'dominant coalition' and that their collective ideology is firmly embedded in the prevailing paradigm, it has been suggested that fundamental changes may have to await disruptive events that remove the basis of their power, such as crises triggered by recession or hostile takeovers (Child, 1977, p105; Pettigrew, 1985, p429). Clearly, in the absence of the kind of shock treatment associated with crises, Tofler's preconditions place a premium on the general management capability or capacity of individual board members and their functioning as a team (Penrose, 1980; Norburn & Schurz, 1984).

Identification of the board as a prime target for development is well established in the literature. The nature of proposed interventions has ranged from awareness that changing organisational culture requires a clear vision of the new strategy and what is required to make it work (Huse & Cummings, 1985), to the specific and urgent need to turn specialists into generalists (Bower, 1970; Garratt, 1987). Despite the difficulties of assessing the effectiveness of particular forms of intervention at board level, the literature on organisational development is well endowed with techniques, among which "teambuilding" is the most prominent. It is beyond the remit of this review to examine these techniques in detail. It is sufficient here to say that these typically involve some combination of experiential learning by confronting board members with real problems, questioning long held assumptions, reflection and reframing, sharing information, gaining commitment etc (Argyris, 1971; Huse & Cummings, 1985; Mumford, 1986).

There is universal acceptance in the literature that attempting to change organisational culture, management styles and organisation structure is a time consuming process. Indeed, the time horizon for strategic change was one of the two key dimensions of Hrebiniak & Joyce's framework. Any approach which purports to shorten time scales has attracted managerial attention. One such approach deserving special mention is that of "action learning", of which the definitive work is by Revans (1982). Practitioners of action learning claim 'accelerated learning' (Casey, 1983, p39) and that it is 'significantly faster and more effective' than other forms of organisational change (Garratt, 1983, p27). Action learning was seen by Garratt (1983, p23) as ....'a process for the reform of organisations and the liberation of human vision', involving the devolution of powers and the recasting of managerial roles. Two statements from Garratt capture the problem of management development at board level and a possible way forward:

> 'Structural elements of Action Learning are that the authority and responsibility for analysis and implementation are given to those people who have psychological ownership of the problem and must live with the proposed solution' (Garratt, 1983, p23).

> 'The necessary psychological condition is for directors to be willing to start letting go of some of their deeply learned specialist thoughts and behaviour, to allow time and space for learning of new attitudes, knowledge and skills' (Garratt, 1987, p45).

Garratt (1987) was particularly scathing about the ability of directors to monitor the external environment, observing that effective directors must 'look upwards and outwards'. He touched on ways of breaking down 'campus thinking' by immersing potential directors in international issues and helping them reframe the way they see their business. But Garratt and other writers have barely scratched the surface of the problem of incorporating the international dimension into the notion of second order change. Although one major feature of the problem was defined some time ago as the managerial attitude of 'ethnocentrism' (home-country orientation) by Perlmutter (1969), it would appear to be an under-researched area of organisational development where practice, particularly in some multinational companies (eg ICI, Unilever, IBM), maybe ahead of the literature.

2.6 MULTINATIONAL COMPANIES AND TECHNOLOGY TRANSFER

2.61 Assessing the Complex Cost/Benefits Associated with Inward Foreign Direct Investment

Throughout the 1950's and 60's the literature on multinational companies and the international diffusion of innovations was largely preoccupied with filling the "technology gap" between Europe and the USA (Diebold, 1968; Servan-Schreiber, 1968; Ohkawa & Rosovsky, 1968; OECD, 1970). Initially, post-war economic growth in Europe was stimulated by the regeneration of manufacturing industry, creating a demand for capital equipment and technology which only the USA was able to supply (Dunning, 1970, p173). By 1960, the role of the USA as dominant generator of managerial and technological know-how was well established and the associated country an firm-specific advantages were exploited commercially through and extensive network of multinational operations.

The search for an integrative model of foreign direct investment and international trade continues unabated. Explanations for particular trading patterns and modes of entry into international markets invariably include the monopolistic exploitation of proprietary technology as an important contribution to competitive advantage. Prominent among researchers and writers on the post-war operation of multinational companies are John Dunning et al of the University of Reading school. Dunning has probably done more than any other academic to improve theorectical and practical understanding of foreign investment decisions by compiling a comprehensive database on international business. His work is at a high level of aggregation but the quality is high and it provides a rich source of research questions for narrower fields of investigation.

From the point of view of the investing company, the focus of attention has been the preference for "internalisation" of firm-specific capabilities instead of using the open market (Coase, 1937; Vernon, 1970; Williamson, 1975; Buckley & Casson, 1976). This assumes that direct investment is superior to other forms of "going international" due to lower relative costs, higher returns and better control. Additionally, the more vulnerable the technology is to imitation, the greater the incentive to internalise (Rugman, 1981).

There is considerable support for the view that inward foreign direct investment has a positive impact on economic and technological progress in the recipient country and industry. Based on his assessment of US investment in the UK over the period 1945-55, Dunning (1958, p190) cited access to the competitive and dynamic qualities of the investors' national economy; and access to R & D, manufacturing and managerial know-how as advantageous to the UK; and that contact of this kind had increased receptiveness to new ideas. Chen (1983, p67) regarded foreign owned subsidiaries as providing a breeding ground for technical and managerial personnel who may later serve local firms or become indigenous entrepreneurs. Gray (1972, p57) wrote of "training up" indigenous workers and raising the general level of technical know-how by involving local supplier firms as subcontractors. Others have emphasised the greater rivalry and competition from the entry of new technology-based ventures by existing firms and new firms aimed at invading established markets (Hill & Utterback, 1979, p321), and when 'ineffective practices come glaringly to light .... even reluctant managers under sufficient pressure seek better production and management techniques' (Quinn, 1969, p154).

Despite the temporal aspect of Dunning's (1958) study he posed two questions which are relevant to the competitive situation of the 1980's: (a) should the UK Government have a well-defined policy on inward foreign direct investment, with controls, and (b) what mode of technology transfer might be the most appropriate for particular industrial sectors? While generally favouring foreign ownership, he went on to write a 'partnership on an equal footing', with the UK not simply a 'buyer of US knowledge'. This seemed to imply that joint ventures or some other form of two-way collaboration might be desirable in the future.

In a study of the consequences for the UK of foreign direct investment, Steuer et al (1973) found some of the popular theories about the advantages unconvincing:

> '.... the very great benefits which some observers expect to follow, on technology grounds, through encouraging inward investment seem to exaggerate spill-over effects, pay insufficient attention to the question as to who benefits from improved technology, and give little weight to alternative ways of promoting technological growth' (Steuer et al, 1973, p9).

They dismissed the view that independent technological capability is essential to UK prosperity and the avoidance of US domination as 'romantic nonsense'. At the same time they recommended itensified monitoring of foreign activity in the UK. Selecting among applicants was rejected, as was keeping them out of certain industries, though they were sympathetic to the idea of an overall (unspecified) general limit. Their chapter on technology was the weakest in the report and it is perhaps indicative of the difficulties they encountered that technology was referred to as .... 'one of the most elusive of the direct investment topics'.

2.62 Intra-Company Channels of Communication

The major criticism of macro-economic models of foreign investment is their preoccupation with capital flows and the tendency to treat technology, information and knowledge as mere factor flows (Dunning, 1958, 1970, 1974, 1980, 1985; Vernon, 1970; Buckley & Casson, 1976; Casson, 1979, 1983; Rugman, 1981). It is, therefore, worth reviewing the findings of the few economists who have had something to say about the transfer and absorption of technological information as part of the internalisation process.

Findlay (1978), for example devised a model which attempted to illustrate that the presence of foreign firms increases the rate of international technology transfer and that when this technology is diffused locally, the rate of technical progress is likely to be higher in that industry. His model was partly based on "contagion theory" (Rogers, 1962; Arrow, 1971) which draws on the analogy that technology, like the spread of contagious diseases, is most effectively transferred by personal contact between supplier and recipient.

Gray (1972, p129) postulated that when a foreign parent company generates a new piece of knowledge, subsidiaries are likely to receive access to that knowledge more quickly than a licensee. He considered the "ownership" element to facilitate the efficient flow of proprietary know-how due to the 'greater awareness and camaraderie between personnel in the parent and subsidiary companies'. In contrast, Crookell (1973, p56) observed that multinationals expect initiatives in communication to originate in their divisions and that .... 'their strength rests less in the power of ownership than in the attraction of competence'. He supported the need to develop 'enduring relationships through which information can flow quickly with the minimum of distortion' and emphasised the need for 'adaptive strength at the receiving point'. Crookell's last point is a function of the parent company's strategy regarding the centralisation or dispersion of R & D facilities and nurturing the critical mass of capability in subsidiaries to assimilate and exploit technology.

2.63 The Location of R & D

A number of writers have noted the historical tendency for most, if not all, R & D activity to be centred in the parent's home country (Terpstra, 1977; Roman and Puett, 1983; Dunning, 1985). Explanations are to be found in the desire among top executives in parent companies to exercise strategic control, to avoid duplication and maintain economies of scale within R & D, often accompanied by an emotional attachment to the R & D function itself. Vernon (1971, p137), for example, refers to subtle geographical biases such as keeping .... 'exciting work close to home'. Caves (1982, p257) writes of effective supervision being seen to depend on keeping R & D investments .... 'within earshot of the parent's head office'. And Stopford & Turner (1985, p164) note an 'headquarters effect' and that .... 'the prime long-term gains come from the location of the brains of the firm'.

Doz (1986) observed that balancing national responsiveness versus integration is a major dilemma for the parent company because proliferation of local R & D projects in response to adaptation undermines the key competitive advantage of spreading cost. From the host country's perspective, centralisation of R & D activities is perceived as undesirable because it leads to technological dependency and runs down creative capacity, thereby blocking opportunities to catch up. Moreover there also appear to be strong feelings that the presence of an R & D function is symbolic of "good citizenship". These arguments have long been used against multinationals, no matter what the state of economic development in the host country. Such arguments also feature strongly in the debate on ethnocentric (home-country orientated), polycentric (host-country orientated) and geocentric (world-orientated) managerial attitudes towards international business operations (Perlmutter, 1969; Heenan & Perlmutter, 1979; Booth, 1979) and the nature of globalisation (Levitt, 1983; Porter, 1986; Douglas & Wind, 1987; Prahalad & Doz, 1987).

2.7 INTERNATIONAL LICENSING AND JOINT VENTURES

2.17 Recent Empirical Research

Macroeconomists have traditionally treated licensing transactions as an integral part of the operations of multinational companies. The dominant perspective in the literature is that of large US multinationals seeking entry into foreign markets via outward licensing, either at an intermediate stage in the progression from exporting to foreign direct investment in manufacturing plants or at some later stage of maturity in the technology life cycle (Posner, 1961; Wilson, 1975; Rugman, 1980). In these respects outward licensing has tended to be regarded as a secondary strategic option, largely related to timing, rather than as a true alternative to foreign direct investment, ignoring many other motivations such as: (a) limitations on the availability of capital, (b) economic and political barriers to entry in foreign markets, and (c) response to currency exchange problems and unforeseen opportunities. Challenges to the prevailing view and contributions to opening up the debate on international licensing transactions have come from a series of independent multi-sector empirical studies by Killing (Western Ontario), Telesio (Harvard) and Contractor (Wharton).

Killing's excellent work is important for his coverage of recipients of technology and his additive approach over several years. His original study of 30 Canadian companies participating in licensing (1977a) was extended to include 10 UK companies (1977b, 1978) and then further extended to examine 37 joint ventures in North America and Western Europe (1980, 1983). Killing (1980, p38) framed his proposition underlying the choice of either inward licensing or joint venture arrangements around relationships: 'The more the technology-dependent firm needs to learn about the business to which the technology relates, the stronger the relationship it needs to form between its personnel and those of the technology supplier'.

Killing sensed the need for "learning" as depending on the extent to which the recipient company is moving away from its established base of knowledge and skills. Licences and joint ventures were, therefore, categorised according to their degree of diversification and the scale of the project for the recipient, in order to show how the strength of relationships develop.

Killing accepted his proposition for licence agreements but rejected it for joint ventures because of the 'unexpected discontinuities' discovered in the 'relatively low use of majority joint ventures and seemingly inappropriate use of 50 percent of joint ventures'. Killing concluded that many firms with valuable technology will not supply it to a joint venture in which they own less than 50 percent. Many technology-seeking firms had tried to set up joint ventures in which they would be majority owner but were offered and had settled for 50 percent ownership. In discussing the international market for technology, Killing (1980, p43) observed that: 'the overwhelming impression is of a small, fragmented, inconsistent market in which buyers and sellers operate with little information', going on to suggest that 'neither buyers nor sellers of technology seem to have a clear idea of the value of the commodity'.

Returning to the theme of communications, the conceptual framework offered by Boisot (1983, 1986, 1987) provides a useful complement to Killing's work on technology supplier/recipient relationships and the mode of transfer. Boisot's basic premise is that the diffusion of knowledge can be described as a pattern of flow and that the rate at which it flows depends on how far it has been codified. He devised a three by three matrix of the degree of codification of knowledge (uncodified, semi-codified, codified) vertically, against specificity of knowledge (firm, industry, market-specific) horizontally.

Boisot suggested that intra-company knowledge is subject to hierarchial considerations and will be codified if the cost is justified by better communication between organisational units. Codified knowledge may require "use of the proper channels" and uncodified knowledge may be limited by the scope for face to face situations. A joint venture is a negotiated relationship which Boisot saw as not easily reduced to a routinised decision-making sequence amenable to hierarchical forms of control. Moreover, the quality of personal contact is important in joint ventures and the way undiffused information is used as a bargaining strength. In contrast, licensing agreements make use of well codified knowledge because of their "arms length" nature and they require less personal contact. According to Boisot's framwork: (a) knowledge transferred internationally within wholly-owned operations is likely to facilitate the full range of codified and uncodified firm-specific knowledge, (b) joint ventures deal mainly in uncodified and semi-codified knowledge of the firm, industry and market-specific kind, and (c) licences involve codified knowledge of all kinds.

The studies by Telesio (1979) and Contractor (1979) take the viewpoint of the licensor. Though rigorous in their use of statistical methods, the level of aggregation is high in both cases and at the expense of assessing managerial behaviour and key firm-specific data. Nevertheless, their findings have been widely quoted by academics and deserve comment here. Telesio examined the operations of 40 US and 26 Western European multinationals and discovered that they did consider licensing alongside direct investment as an alternative, but preferred the latter for its potential for greater returns. 43 multinationals licensed their technology to unrelated companies as a substitute for direct investment or majority joint ventures, and 23 licensed to gain access to reciprocal technology. The last finding may be attributed to the presence of chemical/pharmaceutical companies and electronics companies in his sample and this may also explain why he found few companies willing to divulge to him their royalty rates.

Contractor's research largely centred on the relative amounts of managerial and technological expertise comprising the package and how this is related to the mix of affiliates and non-affiliates and the degree of industrialisation in the host country. Composition of the package was found to depend on the recipient's capability and Contractor noted that the character of the licensor/licensee relationship is the same in both cases (affiliated and non-affiliated). The fundamental difference lies in the closeness of the ties and duration of the relationship. This seems to suggest a tendency towards 'de-facto internalisation' (Cory, 1982, p133). Contractor conceded that global taxation and strategic considerations may over-ride managerial and economic considerations when negotiating compensation.

There have been very few empirical studies on licensing transactions and other collaborative ventures in the UK. Taylor & Silberston (1973) investigated the impact of the patent system and offered a number of useful observations on the incidence and content of particular clauses in agreements. Indeed, because of the importance of industrial property law and competition law, most of the general guides to licensing and joint ventures adopt a legal perspective. Only three empirical studies are of direct interest in this research: (a) the broadly based work of Ryan (1980, 1984) at the University of Bath, (b) the work of Lowe & Crawford in the important area of licensing in small/medium-sized firms (1983a, 1983b, 1984), also at the University of Bath, and (c) a study by Trevor (1985) at the Policy Studies Institute on UK collaboration with Japanese companies.

Ryan's research is valuable mainly for his survey of the content of licence agreements across a range of engineering industries and for his conclusion that: 'technical specifications and the selection of the (technology) supplier are in the hands of engineering management'. This conclusion, coupled with his findings that in over two thirds of his responding companies the initiative was taken by the licensee company, of which three quarters were due to personal contact, suggests that the engineering function may be expected to influence both receptivity to foreign technology and the type of technology acquired.

The research reported by Lowe & Crawford shows that both inward and outward licensing may be attractive to small businesses whose major objective is fast growth, especially where there is a strong desire to remain independent. Their multi-sector study examined size/growth, R & D, environment and culture-related factors and included both UK and foreign sources of technology. Inward licensing firms were found to be generally poorer profit and market performers than those licensing out and those involved in both, though more successful than non-licensing firms. Inward licensing was also found to provide a useful way of widening the product portfolio quickly while offsetting some of the disadvantages of size such as lack of specialist knowledge, scarce cash resources and risk of developing new products.

Trevor addressed the question of whether encouraging Japanese investment and collaborative ventures is likely to foster or hinder the regenerations of UK industry. From 13 case studies in various collaborative situations, he concluded that .... 'the main attraction to the Japanese partner is an increase in market share in the EEC, and concurrently corporate growth and competitiveness'. Trevor observed that UK partners had entered ventures from a position of weakness and saw it as .... 'an exaggeration to see collaboration alone as capable of lending to the regeneration of British industry'. It is difficult to find fault with his overall findings but the report is short on what could be done to remedy the situation and assist future negotiations.

2.72 Learning from the Experience of Other Countries

Most of the literature on recipients of technology through licensing is related to developing countries. The starting point is economic and technological deficiency and ways of providing a countervailing force to the power of multinationals. Strong themes in the literature include: (a) fears about loss of sovereignty and growing technological dependency, (b) the need for agencies acting in the national interest to regulate imported technology, and (c) indigenous capability to absorb and adapt technology and ultimately to improve upon it. Leaving aside the national political issues and problems of poor infrastructure associated with developing countries, there is one area of technology policy that has attracted less attention in Western countries than it deserves - the procedure of "unpackaging" or "unbundling" licence agreements.

The movement towards "unpackaging" by recipients of technology gained impetus in the late 1960's when the United Nations Organisation focussed its attention on the behaviour of multinationals and technology transfer to developing countries. The original model for disaggregating inputs was said to be Japan; which, with guidance from its Ministry of International Trade & Industry, tightly controlled imports of capital and technology during the postwar era. Later, South American countries adopted the procedure and this became a central feature of Decision 24 of the Cartegena Agreement (1970) and subsequent legislation typified by Brazil's Normative Act (1975).

UNCTAD (1972) advised the separation of direct costs (royalties and other fees related to industrial property rights) from indirect costs (purchases of capital equipment and intermediate products and equipment, dividends on equity holdings etc.). The report acknowledged the problem of separating and measuring technological components because of the difficulty of defining a "unit of technology" but urged exposure of the scope available to suppliers of technology for collecting profits and manipulation of transfer prices. Britton & Gilmour (1978) proposed similar unpackaging procedures as an important responsibility of their revamped Foreign Investment Review Agency in Canada, to separate modular ("core") technology from peripheral technology and to ensure maximum benefit for the licensee.

According to Gee (1981, p117): 'Identification of the key technology stripped of its product embodiment constitutes a major step in minimising the influence of disparities in national R & D priorites'. Britton & Gilmour were particularly concerned with Canadian investment in R & D and ways of diluting the unique dependency of their manufacturing industry on the US multinationals. They recommended that inward licensing agreements and joint ventures should be sought in preference to foreign direct investment, with licensing preferred because the licensee is not perpetually tied to a single source of technology.

A second recurring theme in the literature on international licensing is the feasibility of "catching up" with competitors. This is a dynamic situation and as Gold et al (1980, p324) have pointed out: 'adopting available technology, at best, only allows catching up. Competitors continue to advance and there is normally a time lag'. To be able to catch up quickly, technology-seeking firms .... 'have to be thoroughly familiar with the problems, techniques, blind alleys and ideas in the emerging domain' (Gold, 1979, p254). In the case of Japan, Peck & Goto (1981, p627) doubted the simple "catch up" hypothesis, giving the useful analogy that technology is not like water. It does not flow effortlessly from high levels to low levels until they are equalised. They argued that the ability of certain Japanese manufacturers to catch up and surpass foreign competitors is a function of domestic R & D leading to cost reductions, product and process improvements and new product introductions. Continuing use of imported technology was said to be necessary in expectation that significant advances will originate abroad. In similar vein, Blumenthal (1976, 1979) distinguished between "absorptive" and "creative" R & D, the former being directed towards adoption of foreign technology and its adaptation to domestic needs and the latter directed to more original inventions. This ties-in with the notion of "critical mass" of capability mentioned earlier in the context of product innovation and multinational companies.

2.73 Payment for Technology

Most international comparisons of technology flows in the pattern of world trade and investment originate from data presented in national accounts on the "balance of payments for technology". These indicate that in absolute terms, Japan and West Germany spent approximately twice as much on imported technology as the UK and USA in the late 1970's. Viewed from another angle, the ratio of receipts to expenditure for 1984 show Japan and West Germany in deficit with ratios of 0.30 and 0.50, and the UK and USA in surplus with 1.4 and 15.5 respectively (Deutsch Bundesbank, 1986).

From survey data in the Business Monitor M4, it is possible to examine UK trends in receipts and expenditure for related and unrelated companies, and also to obtain a breakdown by industrial sector. In the case of mechanical engineering, for example, royalty expenditures averaged about 14 percent of R & D expenditures in the late 1970's and early 80's, with a ratio of 7:1 for related and unrelated companies, revealing the importance of foreign multinationals as generators and suppliers of technology. A number of writers have attempted to assess the significance of technology transfer in the UK economy by grossing up these data and making assumptions about average royalty rates and sales arising from foreign direct investment (Buckley & Davies, 1979; Davies &

Rosser, 1984). Although statistics of this kind are severely limited by their crudeness and high level of aggregation, they provide a useful starting point for empirical work. As Davies & Rosser (1984, p208) point out, the value of inward technology transfer to UK firms tends to be understated in the statistics because the risk of tried and tested technology is much less than with in-house R & D, and these transfers are too large to be sensibly ignored.

No systematic assessment is available on the magnitude of royalty rates and heavy reliance is placed in the literature on "rules of thumb". Two examples which illustrate the apparent irrationality or lack of knowledge surrounding payments will suffice:

> "Most licensors think that it is fair to ask for a royalty of at least 5 percent and if a downpayment is also required, this could represent something like 60 percent of the profits which the licensee receives in the early years ....' (Kent, 1976, p61).

> '.... when asked about licensing terms, Bendix officials indicated that, if a broad cross-section of American industry were polled, one would find that the average goal is a return to the licensor of one-third of the profits of a well-run, well established licensee with a broad market' (Baranson, 1978, p64).

Clearly, these guidelines suggest a need for empirical investigation of the composition of packages on offer and the ways in which executives arrive at valuations.

2.8 SUMMARY AND CONCLUDING REMARKS ON THE LITERATURE

This critical review has explored the linkages between technology strategy and inward technology transfer at both the macro and micro-levels, and across several broad fields of literature. Given the fragmented nature of the literature, strategic management at the level of individual business units appeared to provide the best integrative framework. The following recurring themes emerged as worthy of special mention in guiding empirical research:

(a) business strategy development is fundamentally a process of matching an organisation with its environment, within resource constraints;

(b) the general manager's role is that of mediator between externally induced change and internal pressures for stability;

(c) antecedents play an important role in shaping internal power structures and the ways organisations respond to strategic threats and opportunities.

The first theme centres on the dynamic interaction of organisations and their environment. This tends to be portrayed in the normative literature as a relatively straightforward, step-by-step process, typically commencing with managerial awareness of a mismatch, triggered by the appearance of a "gap" between expected and current performance. After assessing the magnitude and future consequences of the performance gap, managers then proceed to rationally evaluate/select strategies from an array of options, followed by the allocation/deployment of resources and controlled implementation. Technological inputs to this process are invariably seen as involving the interpretation of technological change and the choice of product/process technologies.

The key lesson from the process school of researchers is captured in the last two themes: that prevailing ideologies and political behaviour impinge on decision processes and outcomes. While empirical studies of business/technology strategy development should retain some of the analytical aspects of normative approaches, they urgently require the real-world corrective offered by socio-political approaches.

The normative stance so evident in the business literature has influenced the treatment of technological issues in two important ways:

(a) Writers have tended to adhere to the Darwinian adage that "classification is the key to clarification", mainly in the guise of high/medium/low technology, stages in the innovation process, generic strategies etc. But business problems, technological change and executive behaviour are dynamic and seldom fit into neat parcels. Moreover, implicit assumptions of homogeneity within classifications often mean that subtle technological contributions to competitive advantage may be lost, or at best, understated. After all, one of the key tasks of strategy formulation and implementation is to create hetrogeneity through differential advantage.

(b) Normative models of business strategy development often label technology as a factor in the external environment or as a "black box" in the internal conversion process. Such models reinforce the apparent need for classification and it is not unusual to find technology appearing as an item in a checklist or position audit. This is consistent with views of technology as a highly contextual factor leaving practitioners to interpret their own particular situation and incorporate the findings at an appropriate stage in the model.

Part of the blame for superficial treatment of technology in the literature lies with the writers and researchers themselves. Business writers, for example, have been drawn towards the more tangible aspects of business, either because they are uncomfortable with the pervasive nature of technological inputs or they lack understanding of the technology itself. Conversely, writers on technology have been slow to characterise the art and practice of technology management and there is a lag in the literature.

Belated awareness of technological contributions may also be attributed to the relative isolation of technological activities within companies due to specialisation. Functional specialisation is mirrored in the way strands of literature have evolved separately to support the scientific and technology-based professions. The integrative mechanism provided by managerial approaches has found a place in the literature on research, design, development, manufacturing and production; but it has been inward-looking and conspicuously lacking in strategic perspectives. It was not until business strategy began to focus on international competitiveness and the effectiveness of scarce resources in the 1980's that a need for the strategic management of technology was recognised. Although it has been shown that formation of a body of literature on the strategic management of technology is still in its infancy, several inter-related issues were uncovered in this review which clearly comprise the core of such literature and need to be addressed:

(a) whether to seek leadership or followership in particular products, markets and technologies;

(b) how to ensure that product and process technologies are representative of international best practice;

(c) whether to close technological gaps by supplementing internally generated technology with externally sourced technology and in what proportions;

(d) how to shift away from traditional emphasis on the short-term productivity of manufacturing operations (within the "black box") towards a more pro-active approach to "customer orientation";

(e) how to achieve greater organisational integration to facilitate exploitation of systems benefits;

(f) how to assimilate new product designs and manufacturing technology (including the inward flow of foreign technology) into existing operations and organisation structures.

To pursue international aspects of technology strategy and technology transfer it was necessary to analyse the literature on multinational companies. This is largely the domain of economists, whose empirical work has tended to be of the cross-sectional, multi-industry, multi-country variety. Consequently, their studies have been at a high level of abstraction, paying scant attention to the major participants in the decision-making process and the organisational context in which technological collaboration is accepted/rejected. Most of the research relates to foreign direct investment. It is only recently that joint ventures and licensing transactions have attracted the attention of academic researchers. Gaps in the empirical literature at the micro-level are substantial. The growing volume of publications and press reports is testament, at least in part, to current interest in these modes of technological collaboration. A parallel trend should be noted in the field of "franchising" in the retail services sector. The following themes have been distilled from the literature:

(a) "ownership" and control relationships may promote or retard the inward flow of technology to UK subsidiaries and joint venture partners;

(b) the appropriate mode of inward transfer is influenced by the amenability of the technology to codification and the capability of UK recipients;

(c) managing the interaction between foreign suppliers of technology and UK recipients is beneficial;

(d) prospective UK licensees and joint venture partners should subject technology packages to a cost/benefit analysis so as to determine incremental contributions to competitive advantage.

Nowhere in the literature is it suggested that foreign sources of technology might replace indigenous capability and provide the total solution to declining UK competitiveness. Rather, writers have stressed the need to increase investment in research, design and development, not only to boost in-house innovation but also to ensure that the skills are available to enable opportunities from foreign technology to be identified, assimilated and exploited.

3. METHODOLOGY

This section reviews the salient features of the methodology and methods used in the research programme. A more detailed account is to be found in Appendix A.

3.1 THE PROBLEM OF OPERATIONALISING THE CONCEPT OF STRATEGIC MANAGEMENT

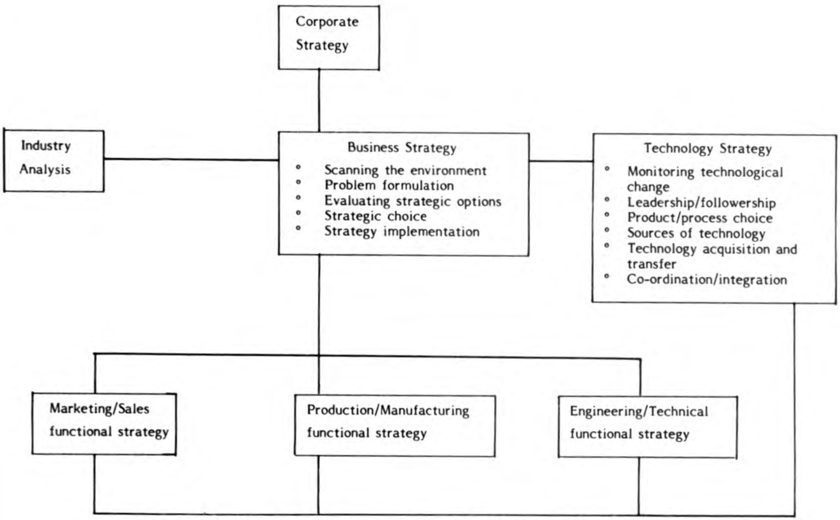
3.11 Towards an Integrative Framework for Strategic Management

There are inherent difficulties in conducting empirical research in the field of technology strategy and technology transfer. These stem on the one hand from the need to maintain a total picture of organisations as complex open systems, and on the other from the pervasive nature of technological inputs to competitiveness and the need to unscramble issues of strategic significance in order to make them comprehensible.

Maintaining an holistic view is of practical importance to general managers who are responsible for overall strategy and concerned with direction and effectiveness. Equally, research purporting to seek improvements in current practice and recommend interventions, must adopt a systematic analysis of strategy development, giving due consideration to socio-political behaviour and interface relationships.

Drawing on the issues raised in the review of the literature in Section 2, it was possible to construct the integrative framework for strategic management research shown in Figure 1. This highlights the central role of business strategy and importance of the business/technology and functional interfaces. As will be discussed later, a number of useful models, schemas and techniques were used within this framework to assist

Figure 1. An Integrative Framework for Strategic Management Research



in operationalising the analytical aspects of the research. That these provide only a partial analysis is accepted, given the dynamic and complex nature of the problem area and in the knowledge that strategic management research is in its infancy.

3.12 The Scope of Research: "Width" versus "Depth"

A review of the literature on research methodology in the general arena of business policy, strategic management and social decision-making revealed a wide range of personal predisposition among writers towards particular research traditions. This is clearly evident in the long-standing, and often fruitless, debate on the suitability of "scientific" and "naturalistic" methodologies in social research (see Hatten, 1979; Duncan, 1979; Das, 1983; Tomkins & Groves, 1983; Miles & Huberman, 1984; Chua, 1986; Strauss, 1987).

Proponents of the scientific approach tend to base their case on the statistical validity of multivariate representations of business strategy which regress combinations of environmental and strategic variables against measures of performance. Such quantitative approaches typically utilise large cross-sectional samples of companies, using factor analysis and clustering techniques to examine statistical correlations and to identify recurring patterns of strategic behaviour. The results have the benefit of generalisability but fail to capture underlying managerial processes and the logic of strategy development.

In contrast, the naturalistic approach has been applied to longitudinal studies which attempt to describe complex dynamic processes over time using a small number of case studies. Qualitative research of this kind aids theory building and provides rich insights into socio-political influences on strategy development, but poses problems of comparison, replication and generalisability.

Of particular interest at the extreme naturalistic end of the spectrum, is the view of Mintzberg (1977) who is intellectually committed to what he calls 'inductive, creative and intensive fieldwork' aimed at conceptual knowledge in preference to 'methodological elegance'. Mintzberg went as far as to suggest that demands for measurement had discouraged policy research and he criticised the growing tendency to focus on well defined, easily isolated phenomena, with measurable inputs and outputs. His views are well supported in the "grounded theory" approach popularised by Glaser & Strauss (1967) and claims by others, including myself, that over-emphasis on the scientific approach often impairs empirical analysis by forcing data into an artificial framework (Lundberg, 1976; Blumer, 1978; Hill, 1978).

In view of the lack of homogeniety within data and taxonomies used by some researchers, and the questionable reliability of their subsequent analyses, I have some empathy with Mintzberg's sentiments. My own view, however, is much less polarised, having due regard for Checkland's (1980) important observation that any given research study is likely to contain both 'hard' (well-defined) and 'soft' (ill-defined) aspects. This suggests consideration of a more pragmatic line of enquiry and the kind of "middle ground" approaches advocated by Burrell & Morgan (1979), Morgan & Smircich (1980), Reichardt & Cook (1980) and Jemson (1981). Reichardt & Cook, for example, regard the scientific versus naturalistic debate as partly dysfunctional because it fosters the belief that the only available option is choice between two extremes, ultimately leading to the (wrong) conclusion that quantitative and qualitative methods are mutually exclusive.

It would seem that there is an increasing willingness among researchers to adopt multidisciplinary approaches and to trade "width" and "depth" in order to get closer to a comprehensive picture which best reflects reality. Jemson (1981), for example, urges researchers to become more eclectic by developing mid-range theories that draw on the existing knowledge base in the disciplines contributing to strategic management. He saw this as providing 'the conceptual building blocks on which integrative, hypothesis testing research can be based'. In similar vein, McGee & Thomas (1986) sought a measure of reconciliation among the various 'disciplinary lenses' through which strategic management has traditionally been viewed, making a plea for 'mixed scanning' perspectives for future advancement in the field. Surprisingly, however, of the 10 lenses they identified (e.g. economic, historical, marketing, political etc), the notion of a "technical" lens was conspicuously absent.

Shrinivastava & Lim (1989) examined 88 strategy-related doctoral dissertations over the period 1960-83 and noted a wide variety of methodologies and disciplinary orientations. Most dissertations were found to be exploratory (54.5 per cent), reflecting the emerging nature of the field, with a trend towards 'interpretive rather than statistical methods of data analysis'. While on the one hand their findings revealed fragmentation, they also saw opportunities open to researchers in having the flexibility to experiment legitimately with new methodologies not constrained by a dominant (disciplinary) orthodoxy.

3.13 Relevance of the Research to Practitioners

Much of the criticism from business executives of academic studies in strategic management may be attributed to misunderstandings surrounding the aims of research programmes, their intended audience and perceptions of relevancy. Questions of relevancy were central to the thinking of Tomkins & Groves (1983), who were concerned with bridging the "schism" between academic research and practitioner needs. To make research less detached and more relevant to practitioners they emphasised the need for research styles and detailed fieldwork consistent with the nature of the problems studied and the underlying ontological assumptions upon which problems are constructed.

Whitley (1984) defined "relevant" research as making a contribution to changing a situation which is regarded as requiring improvement, arguing that it is necessary not only to understand why the situation arose but also to intervene in such a way that the situation is improved:

> 'Any research which is premised upon the objective of change and improvement of social realities must go beyond surface impressions and descriptions if it is to achieve an understanding of how these are produced and reproduced'.

Whitley saw relevant and practically-oriented research as more than "trouble shooting" and simply addressing problems of current interest to managers formulated in their terms. He believes that practically-oriented research does not differ in kind from other intellectual endeavours but added the rider that the need to change beliefs, perceptions and practices means that conclusions must be translatable into everyday terms and be acceptable, at least to some extent, to lay audiences.

From the outset, the relevance of my research to the target audience of industry executives was an important influence on the choice of methodology and methods. Given the scope of the research problem and the objectives stated in Section 1, the decision to adopt an integrative, multidisciplinary approach is considered justified. It was necessary, for example, to ensure sufficient width so as to characterise the competitive environment in which machine tool manufacturers operate, combined with adequate depth and rigour when researching the complex processes of technology strategy development and technology transfer. To this end, my maxim throughout has been to select methods, both quantitative and qualitative, considered to be the most suited to the stage of investigation and the level at which decisions are made.

3.2 RESEARCH DESIGN

The overall shape and phasing of the research programme is illustrated in Figure 2. This commenced with desk research and developed into an intensive exploratory study of the machine tool industry. The specific aims of the exploratory study were:

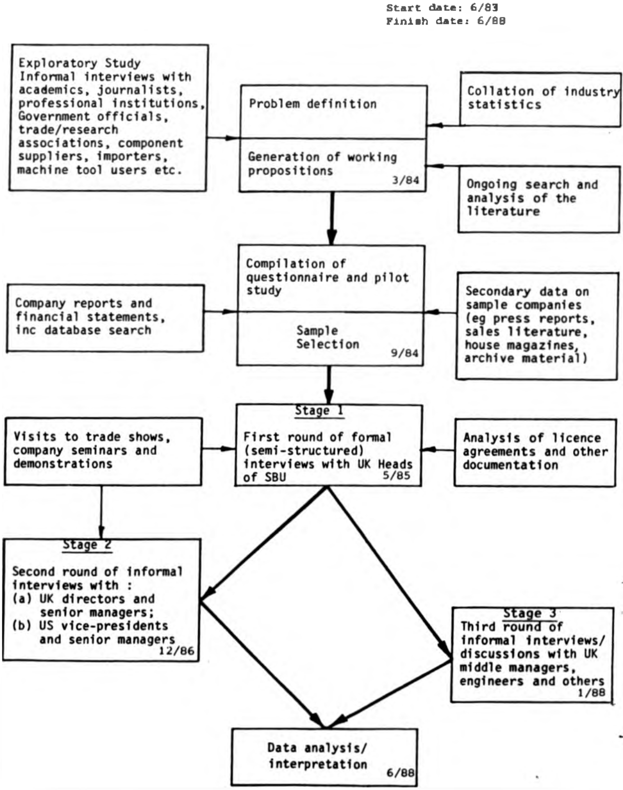
(a) to define the research problem and establish its theoretical underpinnings in the literature;

(b) to ascertain the structure of the industry and gain a thorough appreciation of the antecedents leading up to the problem situation;

(c) to establish the scope of the research programme;

(d) to examine in greater depth some of the "softer" and more "sensitive" elements of the problem situation;

Figure 2. The Research Design



(e) to aid the formulation of research questions that would be used later in the fieldwork phase.

The exploratory study sharpened the search for an approach that would secure an acceptable level of cooperation from participating companies and give representative coverage of the industry. Initially, while industry knowledge was being accumulated and a set of questions formulated, the study was restricted to opinion leaders, reference groups and other external stakeholders. To have included machine tool manufacturers at this early stage would have run the risk of holding incomplete interviews and tainting the sponteneity desired at a later stage. Eventually, however, this restriction was relaxed as it became increasingly necessary to test access to manufacturers and run a pilot questionnaire. Given the sensitive nature of the problem area it was a short step to the selection of personal interviews as the main instrument for data collection. The potential benefits of this method were outlined by Selltiz et al (1959) as:

> '...the unstructured or partially structured interview, if properly used, helps to bring out the affective and value-laden aspects of the subjects' responses and to determine the personal significances of his attitudes...the subjects' responses are spontaneous rather than forced, are highly specific and concrete rather than diffuse and general, are self-revealing and personal rather than superficial.'

Two "friendly" managing directors in machine tool manufacturing companies were approached and they agreed to be interviewed: one in a UK-owned company involved in inward licensing and the other in a UK subsidiary of a US multinational company. The interviews lasted approximately two hours and mainly covered issues related to business strategy and relationships with their respective licensor and parent companies. The learning experience gained from these interviews and the open-ness of the discussion greatly relieved anxiety surrounding both access to senior executives and their willingness to release confidential information.

Examination of industry statistics showed that the machine tool industry exhibits a high degree of hetrogeneity, making stratification or segmentation a pivotal decision in the research design. Segmenting on the basis of machine product technology (ie the method by which metal is removed, formed or handled) was chosen because this is the way specialisation has evolved within the industry. The five main technological segments used in this study are described in Table 1.

These segments represent the full range of intensity of competition and rate of technological change found in the UK machine tool industry. Manufacturers of standard and customised machines or both, were identified in each segment, with some moving towards "systems integration". Collectively, including spares, it is estimated that they accounted for 80-85 per cent of UK production in the mid-1980's.

Table 1. Segmentation of the UK Machine Tool Industry by Product Technology

Turning:	metal chip removal from cylindrical parts where the workpiece rotates and the cutting tool is stationary.
Milling:	metal chip removal from prismatic parts where the workpiece is stationary and the cutting tool rotates.
Grinding:	metal removal using a rotating abrasive cutting wheel. The workpiece normally reciprocates when grinding prismatic parts and rotates when grinding cylindrical parts.
Metal Forming:	the hot or cold flow of metal using pressing, bending and other methods of manipulating the shape of metallic materials.

Automation: a broad category of special purpose equipment incorporating metal cutting, forming and handling processes (e.g. automated assembly machines, transfer lines, robotic loading devices).

3.3 CONCEPTUAL AND ANALYTICAL FRAMEWORK

The over-arching dynamic framework of strategic management adopted in this research is applied at the level of individual manufacturing "strategic business units" (SBUs). These are defined here as autonomous profit centres with their own set of competitors and a Head responsible for overall strategy development. The term SBU is normally used in the context of divisions within groups of companies but is equally applicable to independent companies, including those which are owner-managed.

Selection of the SBU as the "unit of analysis" facilitates exploration of the problem of declining international competitiveness at a level consistent with the aims of the research. Specifically, this allows empirical research to:

(a) focus on the problem owners in their organisational setting;

(b) examine the process of strategy formulation/implementation and the acceptability of prescriptions which involve the sourcing of foreign technology;

(c) assess the extent of functional differentiation/integration;

(d) examine the resource allocation process;

(e) identify sources of sustainable competitive advantage residing in products, markets and technologies;

(f) diagnose competing forces for stability and change, and assess the implications for management/organisational development interventions.

A central feature of my attempt to operationalise this framework is the set of seven working propositions shown in Table 2. These propositions were generated largely from key issues emerging from the critical review of the literature and are to some extent grounded in my personal experience.

The first working proposition (WP1) examines the nature of "technological gaps" and how technology, specifically foreign technology, enters the decision-making framework. The wording of this proposition contains the corollary ...."moderated by internal political behaviour", representing my deliberate attempt to highlight at the outset that power relationships and political contingencies are important intervening variables. The second proposition (WP2) and two subsequent inter-locking propositions (WP3 and WP4) explore relationships between product engineering, marketing and manufacturing activities and how these influence the prevailing internal environment in which foreign technology is assimilated. And finally, three propositions (WP5, WP6 and WP7) analyse the characteristics and relative merits of the three principal modes of inward technology transfer.

Testing propositions using multidisciplinary approaches may lack the methodological elegance of single disciplinary approaches but the benefits of realism were considered to far outweigh any loss of rigour and precision. It is doubtful anyway whether such precision is possible or appropriate in the study of strategy development. I had few reservations about taking the propositions and seeking acceptance/rejection by confronting them with careful fieldwork and

Table 2. Working Propositions Related to Machine Tool Manufacturers in the UK

Working Propositions		Main Sources
WP1	The probability of closing technological gaps using foreign technology is enhanced by an internationally-oriented top management and moderated by internal political behaviour.	Rogers (1962), Schon (1967), Mintzberg et al (1976), Hage (1980) Lyles (1981), Goldsmith & Clutterbuck (1987).
WP2	Technology strategy development is dominated by product engineering considerations to the relative neglect of marketing and manufacturing/production activities.	Woodward (1965, 1970), Shanklin & Ryans (1984), Sciberas & Payne (1985), Hill (1983), Bolwijn et al (1986).
WP3	Failure to manage internal relationships (e.g. the coupling between product and process) and external exchange relationships (e.g. interaction with sub-contractors, component suppliers and customers) as an integrated system involves sacrifice of sustainable competitive advantages.	Schonberger (1982), Haakansson (1982, 1986), Voss (1986).
WP4	Current organisational structures present a barrier to the inward transfer and assimilation of foreign technology.	Lawrence & Lorsch (1967), Allen & Cohen (1969), Bhattacharyya (1985), Ingersoll (1987)
WP5	Strategic benefits accrue to licensees who "unpackage" agreements when evaluating the technology on offer from foreign licensors.	Simon (1957), March & Simon (1958), UNCTAD (1972), Vaitsos (1974), Britton & Gilmour (1978).
WP6	The closer the machine tool technology is to the state of the art, the greater the need for close relationships between technology supplier and recipient.	Rogers (1962), Arrow (1971), Gray (1972), Killing (1977, 1980, 1983), Boisot (1983).
WP7	Foreign parents of UK subsidiaries operate an international technological division of labour; centralising their research, design and development activities in their home country, and to the detriment of the UK industry.	Vaitsos (1974), Caves (1982), Stopford & Turner (1985), Doz (1986).

Note: Additional propositions related to narrower aspects of the research are raised at appropriate points in the analysis presented in Section 4.

intellectual argument.

The foregoing comments do not pretend to hide the difficulties I encountered in collecting, ordering, analysing and interpreting data. An accepted method of dealing with such complexity, however, borrowed from social science research, is that of compiling case studies and extracting themes. Despite the shortcomings of replication and validity, this method was adopted in a way that minimised the potential distraction of technological detail, yet allowed data to be distilled and presented thematically for analysis under the working propositions.

To boost the analytical power of this approach and move beyond description towards understanding and explaining strategic behaviour, several models were used. The most important of these is the robust four-strategy schema of leadership, fast followership, late followership and niche exploitation. I chose this schema because: (a) it is based on timing and may be related directly to the dynamics of the technology life cycle, providing a familiar point of reference for examining relationships between product and process, and (b) it is possible to observe different strategic responses at various stages in the cycle. Products/processes originating from both in-house development and inward technology transfer fit comfortably with this schema. One particular advantage, for example, is that of tracing the "mobility" of SBUs which had used technology to re-position themselves. As will be discussed later, I expected, a priori, that "buying lead time", as in the case of say a shift from late follower to fast follower, would be an important motivation underlying inward licensing.

3.4 THE SAMPLE OF MACHINE TOOL MANUFACTURERS

The sample comprised manufacturers drawn from the UK and US machine tool industries.

Using directories, exhibition guides and the advice of opinion leaders it was possible to locate and cross-check the existence of 330 "suppliers" of stand-alone machines and systems in the UK in the five technological segments identified. Of these, 205 were regarded for the purpose of this research as manufacturing SBUs, thereby representing the best estimate of the population. From this population I envisaged that about 50 SBUs could be visited to interview the target respondents and others without imposing constraints on selection due to geographical location.

A judgmental sampling procedure was preferred to ensure the inclusion of:

(a) at least the top three SBUs in each technological segment, based on annual sales turnover;

(b) a mix of SBUs which allowed comparison of technology strategy development in UK-owned independent companies and subsidiaries of larger engineering groups, both active and non-active in licensing; and foreign-owned companies using technology supplied by the parent company and licensing technology from outside the group;

(c) SBUs which had made a significant technological contribution to the industry not reflected in their annual sales turnover.

Initially, 38 SBUs were identified as desirable for inclusion in the UK sample. Later, a further 27 SBUs were added on a "snowball" (series) basis, giving a total cumulative sample of 65 SBUs. Of these, 54 agreed to cooperate, resulting in a response rate of 83 per cent. The main advantage of the snowball sampling technique was that it recognised the cumulative learning process and allowed SBUs to be included that were perceived by respondents as competitors, rather than relying solely on my own judgment.

The sample drawn from the US machine tool industry was constrained by time and cost. I decided that over a period of one month (20 working days), it would be possible to visit 10 companies in four geographic locations and, additionally, to spend at least five full days meeting executives from other companies at the International Machine Tool Show in Chicago.

The general aims of the visit to the USA were:

(a) to meet senior executives connected with the transfer of technology from the US to the UK;

(b) to cross-check strategic issues emerging from the earlier interviews with UK Heads of SBUs;

(c) to explore perceptions of the US/UK relationship and gain insights into factors impinging on policy decisions affecting UK operations;

(d) to see their manufacturing facilities;

(e) to characterise patterns of adoption of certain key technological innovations.

8 of the 10 US companies visited were parents of UK subsidiaries and 2

were licensors of UK companies. Contact was made with the US companies through the Head of the UK subsidiary or licensee and all agreed to cooperate. Senior executives and other staff in a further 11 companies having formal technology transfer agreements with UK companies were approached during the week at the trade show.

3.5 DATA COLLECTION AND ANALYSIS

Data was collected in three main stages by personal interviews. The first stage was completed as quickly as possible and before commencing stages 2 and 3. As indicated in Figure 1, the last two stages overlapped.

The first stage targetted UK Heads of SBU. The strategic management capability of the Head is regarded as critical to the success/failure of the SBU and he was the person most likely to provide a strategic overview. He also possessed the authority to disclose details on strategic issues and provide access to senior managers and other staff.

Contact was made with Heads by personalised letter on Coventry Polytechnic headed note paper. Each letter briefly mentioned the scope of the interview, emphasising strategic issues and inward flows of technology. Assurances of anonymity, confidentiality and non-alignment with competitors were given. Letters were followed up by telephone and interviews of about one hour's duration were requested to take place in his office. The location was deemed to be important because it allowed observation of the respondent's behaviour in his own surroundings and facilitated access to documentation. A total of 45 Heads agreed to be interviewed, representing a response for this target group of 83 per cent. In practice, the duration of the interviews was typically extended to two hours or more, with many opportunities to explore side issues over lunch and during factory visits.

The main instrument for gathering data in this group was the semi-structured questionnaire. This method was chosen principally because of the need to elicit responses on a range of common topics across the sample and to facilitate comparison.

The second stage involved informal interviews with two groups: UK directors and senior managers, and US vice-presidents and senior managers.

Interviews were held with UK directors and senior managers in a subset of SBUs. Respondents were drawn from the three main functions of marketing/sales, engineering/technical and manufacturing/production. Each was approached either by letter or telephone, again requesting to meet them at their office. These interviews provided the opportunity to triangulate earlier data and probe sensitive areas such as cross-functional reltionships and internal power structures. By meeting respondents in their functional setting it was also possible to observe the extent of office/factory automation, office geography, status symbols, day-to-day procedures etc. This group, together with the Head, comprise the "dominant coalition" and were frequently re-visited to validate my findings.

Interviews with US vice-presidents and senior managers mainly focussed on gathering data on relationships with their UK subsidiary or licensee, the differences between US/UK operations and detailed mechanisms of transferring know-how. This enabled several themes to be explored which would not have been possible without the opportunity to tie up both ends of the transfer chain.

The third stage comprised data collection from a wide variety of informal interviews, meetings and conversations with middle managers and lower level staff. Multiple methods were used to acquire data and uneven access precluded the same level of consistency as in the previous two groups of respondents. My aim was primarily to probe the softer areas of company operations, to gain a feel for the nature of temporary/enduring sources of competitive advantage. A special effort was made to meet applications engineers in all SBUs because they were felt to provide reliable comment on the adoption of product innovations, problems at the customer interface and competitor activity. Similarly with engineers in the manufacturing area. It was considered essential, for example, to gain an operations perspective on the assimilation of inward manufacturing process know-how in UK subsidiaries of US parent companies and UK licensees.

Data analysis in my research tended to take place alongside data collection in each of the 3 stages, as part of a continuous learning process. Notes were taken during the interviews and written up immediately afterwards. Hard data was often coded for subsequent analysis. Soft data went through an interactive process of summarising, cross-checking and aggregating with secondary data to build up concise company profiles. Validation was continually sought by taking multiple perspectives and, where possible, via 'triangulation' with documentary evidence (Denzin, 1970, Jick, 1979).

3.6 A SHORT CRITIQUE OF THE METHODOLOGY

(a) The adoption of an integrative multidisciplinary approach was satisfactory, though somewhat cumbersome. Careful thought was given, a priori, to the systematic acquisition and handling of vast amounts of data; but the effort required in codification, cross-referencing and extracting themes for discussion under the seven working propositions was underestimated.

(b) Given the fragmented nature of the machine tool industry and the problem of incomplete data at the SBU level, it is doubtful whether a more quantitative approach overall would have been possible and/or appropriate. A more rigorous application of statistical techniques in narrower areas, however, may have benefited the interpretation of attitudinal data and cross-functional linkages. Discussion on generalisability of the research is to be found in Section 6 and references to shortcomings of the research in specific areas is deferred to the context in which they arise in Section 4.

(c) Any bias entering the analysis may be largely attributed to my state of familiarity with the industry during the early round of interviews and my own "disciplinary lens" failing to detect nuances of significance to the line of questioning being followed. These were partially offset by conducting a pilot study, through triangulation and confronting areas of perceived difficulty with colleagues.

(d) With hindsight, it would be wise for research of this kind to be either narrowed down by splitting up the work among multiple researchers, or limiting the investigation to companies participating in just one of the three modes of inward technology transfer. The former would, inevitably, require greater co-ordination and involve some loss of consistency. The latter would sacrifice coverage of the impact of technology transfer on the industry. The former is preferred and it is hoped that this research will be extended and partially replicated in other engineering industry contexts.

4. RESULTS AND DISCUSSIONS

This section presents discussion of the research findings under the seven working propositions. Supporting data and analysis is to be found in Appendix B.

4.1 RECEPTIVITY TO FOREIGN TECHNOLOGY

The first working proposition is:

> The probability of closing technological gaps using foreign technology is enhanced by an internationally-orientated top management and moderated by internal political behaviour.

4.11 Radius of Competition

4.111 The UK

Broad insights into the international orientation of senior executives were gained initially by exploring their perceptions of "radius of competition". In essence, this invited them to define the geographical areas in which their SBU is active and the origin of competition, while simultaneously revealing first indications of an hierarchy of competitors and the intensity of competition in different technological segments.

The UK was chosen as the starting point for discussion by executives and they appeared to feel at ease when describing the position of their SBU in relation to other UK manufacturers and importers. There was good awareness of structural characteristics of the industry such as machine tool production, sources of imports, destination of exports, etc., based on statistics collated and disseminated by the Machine Tool Trades

Association. It is believed that this initial emphasis by executives on the UK should be largely attributed to them finding a convenient way of ordering replies and no attempt was made to impute ethnocentric tendencies at this stage. 'Moving within the machine tool and user industries' was frequently mentioned by executives as indicative of their "external" orientation but this was not always synonymous with "international" orientation. A number of executives in larger SBUs, for example, were participating in the activities of the Machine Tool Trades Association (MTTA), the Machine Tool Industry Research Association (MTIRA) and other bodies at industry level. Not surprisingly, the same names were to be found on lists of delegates at conferences, making submissions to parliamentary committees and quoted in the press as opinion leaders on the state of the industry. Overall, however, the industry was found to be poorly represented at both national and international level. The MTTA lacks the strategic vision and techno-commercial initiatives taken by its foreign counterparts. It has only partially performed the coordinative role between government and its member companies, leaving the onus on the latter to respond to international competition. This is not to suggest that individual machine tool manufacturers should rely totally on collective action. The critical point is that as a small, fragmented industry with declining lobbying power, it has lost the ability to shape and stabilise the trading environment to its strategic advantage.

While many executives had grasped the significance of internationalisation and could offer instant opinion on almost every aspect of the industry, some had spent inordinate amounts of time on their external, almost ambassadorial, commitments and neglected their executive role. In several interviews, occasions arose when further probing of competitor awareness had to be re-directed or postponed to avoid embarrassment. One executive, for example, the managing director of a well known company and a prominent figure in the industry, was about to launch a new range of computer numerically controlled (CNC) machines in a crowded segment of the market. When asked about his expectations for the machines and which competitors would be the ones to watch, he proffered a target market share (unrelated to time period) and struggled to name three competitors, two of which were clearly not direct competitors. After fumbling unsuccessfully through a copy of the corporate planning document, he conceded that he 'left that sort of thing to his sales director'.

Most executives were able to name the leading competitors in segments of interest to their SBU in the UK but there were marked differences in their detailed knowledge of the competitive situation in the major machine tool producing/consuming countries. In order to assess these differences, Heads were asked to rank the state of their SBU's knowledge of competitors and market requirements in the US, Japan and West Germany. The results are shown in Table 3 and each country will be considered in turn.

Table 3. The Head of SBU's Ranking of Knowledge on the Competitive Situation in the Top Three Machine Tool Producing Countries.

Country	Ranking		
	First (%)	Second (%)	Third (%)
USA	69	23	8
Japan	0	21	79
West Germany	31	56	13

N=39 SBUs

4.112 The USA

The USA is the largest consumer of machine tools and has the largest installed machine tool base. It can be seen from Table 3 that it is also the best known to executives within the UK industry, mainly because of the historical level of US direct investment, the importance of the US as the major destination for UK exports and, of course, common language. Statistics are readily available on the US market and it is well served by the technical press.

The interviews revealed that it cannot be automatically assumed that executives in US-owned SBUs are better informed about the US market than executives in UK-owned SBUs. The nature of their contact with the US market is often very different: US-owned SBUs, for example, have indirect contact through their parent company with the benefit of an "insiders' view"; whereas UK-owned SBUs have a combination of direct and indirect commercial contact via agents/distributors, sales/service visits etc. This provided two different perspectives on the same market:

(a) Executives in the 17 US-owned SBUs studied demonstrated comprehensive knowledge of the changing structure of the US industry and the plight of US manufacturers. Executives were pleased to have the opportunity to air their views and this also revealed some of the pressures imposed by US ownership. Many had great faith in the dynamism of the US economy and its ability to recover.

(b) Executives in the 37 UK-owned SBUs offered a more pessimistic view on the state of the US market and there was wide variation in their awareness of developments. Though the best knowledge was found among the 56 per cent of SBUs actively exporting to the US, there was a tendency to dwell on the tactical situation surrounding particular orders rather than to expand on the longer term impact of structural change.

4.113 Japan

Japan is the largest producer of machine tools worldwide and is the second largest exporter after West Germany. Import penetration in Japan is negligible. Thus Japanese manufacturers enjoy the enviable position of dominating their thriving domestic market, while competing overseas with local producers on their own ground. The need for an "insiders' view" on Japan is underlined by the UK trade statistics which show that since the mid-70's, Japanese manufacturers have moved from seventh to second largest source of imports, closely behind West Germany.

The top 5-10 Japanese manufacturers have concentrated on general purpose CNC machines and this provided the main discussion point among executives in about one third of SBUs studied. The activities and aspirations of this high profile group of Japanese manufacturers has been well documented and over the years executives have observed them building up a superior global position. Many executives believed the Japanese domestic market to be almost impregnable and their export drive implacable.

Executives in SBUs producing special purpose equipment and highly customised machines were beginning to show more interest in Japan. Previously, they had seldom met up against Japanese manufacturers and there was a long-standing assumption that the manufacturer/user relationship implied in "customisation" provided a barrier to their entry to the export field. Overseas investment by Japanese motor vehicle manufacturers and machine tool manufacturers has modified earlier views and the role of the former as a specifier cannot be ignored.

Knowledge of Japanese machine tool manufacturers was sketchy, to say the least. Little appears to be known about the large number of so-called "second division" Japanese manufacturers and even less about the customer base. Executives generally agreed that first hand experience is the only way to monitor developments in Japan but there were few signs that an intensive intelligence gathering exercise was a priority.

4.114 West Germany

Discussion on West Germany was approached in the context of the EEC. Unfortunately, this proved to be a frustrating exercise in which many lines of questioning were abandoned. UK membership of the EEC aroused minimal interest and the role of West Germany as the dominant machine tool producer/exporter has received passive acceptance by most sections of the UK industry. Two factors suggest that the status quo is unlikely to be challenged:

(a) The machine tool industry reflects the relatively low proficiency in European language skills throughout the UK. Only 9 senior executives claimed to be capable of holding commercial/technical conversations in a second European language and of these, only 4 had lived and worked in a non-English speaking country for an extended period. Formal training in languages was offered in 3 SBUs.

(c) Intra-Community trading has settled into a stable pattern. Over the period since accession to the Treaty of Rome in 1972, other member countries have accounted for a steady 48-55 per cent of total UK imports and 20-25 per cent of exports.

It was only when two issues concerning West Germany were introduced into the discussion that any substantive response was forthcoming. These issues were the ascendency of Siemens as the leading European controller supplier and the increasing number of prestige UK orders for high value-added machining cells being won by West German manufacturers, notably Scharmann, Werner and Hauni Blohm. Only executives in SBUs facing direct competition from West German manufacturers were able to elaborate on comparative strengths/weaknesses and develop a coherent view of the competitive situation in Europe. The notion of the EEC as the "domestic" market for machine tools was remote for most executives and 1992 seemed a long way off!

4.12 International Business Operations

4.121 The scope of international activities

From the previous wide-ranging assessment of radius of competition it was clear that the perception of some executives was based on first hand experience of international operations, whereas that of others was heavily influenced by secondary sources such as trade associations and technical journals. In order to deal with responses in a systematic way and to get behind the "public face" image often projected by front-line executives, it was decided to gather data on the extent of their international activities in such areas as exporting, overseas manufacturing/assembly, importing and licensing. These provide the context for proxy measures of the international orientation of senior executives.

Table 4. Exporting, Importing and Licensing Activity by Ownership of SBUs for 1984

Ownership	Percentage of SBUs in Each Category of Ownership Active in:				
	Exporting	Importing	Inward Licensing	Outward Licensing	Inward and Outward Licensing
UK-owned Independent SBUs (22% of sample)	100	64	45	9	9
SBUs of UK Engineering Groups (35% of sample)	95	58	47	21	21
SBUs of UK M/C Tool Groups (12% of sample)	100	29	29	0	0
SBUs of US M/C Tool Groups (31% of sample)	94	88	18	18	6
All SBUs N=54 SBUs	96	65	35	15	11

Table 5. Sales of Exported Machines as a Percentage of Total Production by Ownership of SBUs for 1984

Ownership	Percentage of Exporting SBUs in Each Category of Export Ratio:				
	<10%	10-29%	30-49%	50-69%	70%+
UK-owned SBUs (69% of Exporters)	27	24	22	11	16
US-owned SBUs (31% of Exporters)	12	24	18	28	18
N=52 SBUs					

A breakdown of the international operations for the sample of 54 SBUs by type of ownership is presented in Table 4. This data was obtained from the interviews and suggests that a significant degree of management attention is devoted to international activities in most SBUs.

4.122 Export distribution channels and overseas production

The high proportion of SBUs in the sample active in the export field is not surprising given that UK exports were running at the rate of 45-50 per cent of total production throughout the 1970's and early 80's. Export ratios, however, are notoriously difficult to interpret at such a high level of aggregation and it is only at the SBU level that a meaningful assessment can be made. The ratio can vary considerably in machine tools with the placing, loss or deferment of a few large orders. Some SBUs have become increasingly dependent on exports as their home market has declined. Table 5 shows the spread of export ratios by type of ownership and points to the danger of making generalisations about export performance. Underlying the data are two important trends which raise questions about the true extent of executive's exposure to international operations:

(a) UK-owned SBUs have been reluctant to set up overseas manufacturing/assembly plants and tend to export machines via networks of independent agents/distributors. Only 11 per cent of SBUs studied had invested in overseas plants and 18 per cent in wholly-owned sales offices. This compares poorly with Japanese and West German manufacturers who have invested heavily overseas in the 1980s, especially to protect their market position in the US.

When it was put to executives that there is merit in establishing a "permanent" presence in certain key countries, not only for selling purposes but also to monitor competitor and customer activities, there was good appreciation of the benefits. Their over-riding objective, however, was invariably stated as 'the need to fill UK capacity first' and there was widespread perception in SBUs of larger groups that investment proposals would be unlikely to receive corporate approval. The last point regarding decision-making behaviour at the corporate/SBU interface is important and will be taken up again later in this sub-section.

(b) US-owned SBUs had achieved export ratios marginally higher than their UK-owned counterparts but over half of these were known to be exporting machines destined for the US via their parent company. Often these exports comprised part-finished machines to take advantage of temporary cost and currency differentials, suggesting that some orders were "placed" rather than "won".

4.123 Importing

Examination of importing activities revealed many linkages with reputable foreign principals, representing an important inward transfer of product knowledge. The extent of importing by type of SBU ownership is shown in Table 4 and a breakdown by import ratio in Table 6.

Table 6 indicates the spread of import ratios and like the data on export ratios, conceals important trends relevant to the involvement of executives in import operations:

Table 6. Sales of Imported Machines as a Percentage of Total Sales by Ownership of SBUs for 1984

Ownership	Percentage of Importing SBUs in Each Category of Import Ratio: <10%	10-29%	30-49%	50-69%	70%+
UK-owned SBUs (57% of Importers)	35	20	20	15	10
US-owned SBUs (43% of Importers)	40	27	13	13	5
N=35 SBUs	Note: Figures exclude kit assembly				

(a) 57 per cent of SBUs of UK machine tool groups and 11 per cent of SBUs of UK engineering groups were not active in importing due to separate SBUs being given this responsibility;

(b) 65 per cent of US-owned SBUs were importing machines from their parent company or another division within the group.

4.124 Licensing

Referring again to Table 4, deeper examination of the incidence of licensing activities completes the picture. Of the 54 SBUs studied, 19 (35 per cent) were involved in "inward" licensing. Of these 19 licensees, 18 (95 per cent) were exporters of machines, 15 (79 per cent) importers, and 14 (74 per cent) involved in both exporting and importing operations. Of these exporting/importing SBUs, 8 were involved in "outward" licensing and 6 of these were also licensees. This evidence suggests the convergence or mutually reinforcing effect of international operations in some SBUs. It is not regarded as coincidence that executives in the 6 SBUs active across the full range of activities were among the most travelled, that 4 of these SBUs had above-average export ratios and 2 had overseas manufacturing/assembly operations.

4.13 International Orientation

4.131 An international learning effect?

The evidence presented so far is largely extracted from cross-sectional data and has captured the "outcome" of earlier decisions (ie those international business arrangements reaching fruition and current at that "snapshot" in time). To assess the international orientation of senior executives, it is also necessary to add a longitudinal component related to cumulative learning and experience.

At the individual level this involves continuous updating of knowledge, skills and experience. At the SBU level, the stock of knowledge and mix of skills/experience is integrated into the prevailing culture. This is a complex and dynamic situation, not easily reduced to a set of quantifiable dimensions and deserving more rigorous treatment than intended here. Nevertheless, by examining: (a) the recent travelling patterns of senior executives, (b) their participation/attendance at international trade shows, and (c) setting these against their background experience of international operations; it is possible to explain, albeit crudely, their predisposition towards foreign technology. The data on overseas visits made by Heads and Directors responsible for the three main functional areas is shown in Tables 37 and 38 and the findings will now be summarised by SBU ownership.

4.132 UK-owned SBUs

Marketing/Sales Directors were the most frequent visitors to Europe and the US, closely followed by Heads of SBU and Engineering/Technical Directors. Overseas visits by Manufacturing/Production Directors tended to be limited to trade shows within Europe and to assess potential machine purchases for their own plant. Japan was the least visited country by all executives and most of the recent visits were connected with inward agency and licence agreements. Normally, the main purpose of an overseas trip to any country would be to service export agents and customers. The existence of inward licensing arrangements was found to be an important additional factor in justifying extended visits to the US and most executives said that they had benefitted significantly from exposure to their licensor's operations and customers.

An investigation of UK-owned SBUs exhibiting at major international trade shows in the early 1980s (i.e. Paris, Hanover, Chicago and Osaka) indicated decreasing participation with increasing distance from the UK. The relative merits of the shows in Paris, Hanover and to a lesser extent, Chicago, frequently entered discussion. Osaka was considered beyond their resources and aspirations. There was little evidence to suggest that participation was part of a systematic campaign to increase penetration overseas and the level of discussion seldom moved beyond criticism of the growing cost of setting up and manning a stand. Both exhibiting at, and visits to, foreign trade shows were severely curtailed by most SBUs during the recession.

4.133 US-owned SBUs

Heads of SBU and Marketing/Sales Directors were the most frequent travellers within Europe, with a typical visit lasting no longer than about three days. Heads were generally more mobile internationally than their counterparts in UK-owned SBUs; partly as a consequence of foreign ownership and the requirement to attend parent company board meetings, and partly due to their responsibility for European subsidiaries. Marketing/Sales and Engineering/Technical Directors visited their US parent company to attend sales meetings and project review meetings respectively, often timed to coincide with some special event such as an industry conference or trade show. It was also clear that the incidence of visits to the US by middle managers and engineers exceeded that found in UK-owned SBUs. As in the previous case, Manufacturing/Production Directors were the least travelled.

Underlying the data was a strong commitment among US-owned SBUs to trade shows as a means of maintaining visibility world-wide. Participation and attendance depended largely on the parent company's allocation of territories to their network of sales and manufacturing subsidiaries. In the case of Japan, for example, US parent companies normally retained responsibility for exploitation themselves, thereby limiting the exposure of UK-based executives to an important source of competition.

4.134 Predisposition towards foreign technology

When the foregoing evidence is interpreted against the data in Table 7, a useful picture of international orientation begins to emerge. Because the measure of predisposition towards foreign technology in Table 7 is based on perceptual data, it represents a composite of all learning and experience. The following observations summarise the findings:

(a) Heads of most SBUs, irrespective of ownership, who have had experience in the inward licensing of foreign technology from unrelated companies appear to be happy with this mode of transfer.

Table 7. The Head of SBUs' Predispositon Towards "Inward" Technology Transfer via Licensing, Joint Ventures and Direct Investment

Ownership		Predisposition Towards Licensing Favourable (%)	"Don't Know" (%)	Unfavourable (%)
UK-owned SBUs				
involved in inward licensing	(N=16)	69	6	25
not involved in inward licensing	(N=21)	38	43	19
US-owned SBUs				
involved in inward licensing	(N=3)	100	0	0
not involved in inward licensing	(N=14)	64	14	22
		Predisposition Towards Joint Ventures		
UK-owned SBUs	(N=37)	41	38	21
US-owned SBUs	(N=17)	59	17	24
		Predisposition Towards Direct Investment		
UK-owned SBUs	(N=37)	32	43	25
US-owned SBUs	(N=17	41	24	35

(b) The high predisposition towards joint ventures, particularly among US-owned SBUs is surprising given the lack of experience of this mode in machine tools. Executives in US-owned SBUs tend to be more comfortable with shared equity arrangements than executives in UK-owned SBUs.

(c) Heads of US-owned SBUs appear to be dissatisfied with inward technology transfer via direct investment. Discussion of whether this amounts to rejection of intra-company transfer or is related specifically to temporal aspects of US ownership will be deferred to a later sub-section.

(d) "Unfavourable" responses of the order 20-25 per cent are associated with the identification of a "negativity" bias. This surfaced during the interviews with some executives, particularly in long-established SBUs, and was often rooted in events stretching back two or three decades, suggesting that executive's age and tenure are important variables in the learning process. Overall, it was bad experiences that were given the most airing in the unsolicited sense and good experiences had to be probed in a soft, indirect way. This is an important observation because past experiences of success/failure in international operations were found to respectively widen or constrain executive's consideration of strategic options involving foreign technology.

(e) The high proportion of responses in the "don't know" category among UK-owned SBUs reflects a combination of agnosticism towards foreign technology and lack of awareness. Either way, this has identified a target for intervention. Recent developments related to the sourcing of technology from Japan may be expected to provide a powerful influence on inductive learning in SBUs in the "don't know" category. Executives in all but the most laggardly SBUs were closely watching this emerging cluster of agreements.

Taken together, the evidence presented under the first part of this first working proposition has established that the probability of closing technological gaps using foreign technology is, indeed, enhanced by an internationally orientated top management. The research will now proceed to examine the mechanism by which foreign technology enters the decision-making framework and the moderating effects of political behaviour stated under the second part of the proposition.

4.14 Environmental Scanning Behaviour

4.141 Partitioning of the external environment based on technological specialisation

As discussion of the radius of competition widened, technological specialisation featured strongly and executives quickly centred on the way particular segments were dominated by manufacturers from certain countries. Typical generalisations included the strength of Japanese manufacturers in CNC lathes and machining centres, West German and Swiss manufacturers in precision grinding machines, US and West German manufacturers in transfer equipment, etc.

Technological specialisation at the level of individual SBUs and their narrower specialisation in product/market niches has led to heterogeneity in machine tools and severely limited some executives' perception of their domain. Diffusion of CNC technology provides many examples where partitioning of the environment obscured signals of technological change and the evolution of product/market segments. Had some executives scanned developments on a wider front, they might have been better equipped to answer such strategic questions as: (a) how can we ensure that what happened in other segments will not happen to us, (b) how are advances in automation, robotics, assembly equipment, etc. likely to blur the traditional boundaries of the industry, and (c) what are the time scales and what new competitors might this bring?

Informal, and often haphazard, monitoring of the external environment was widely practised by executives in all SBUs studied. In the case of inward licensing opportunities, for example, the initiation of over two thirds of the 31 agreements was attributed to chance meetings and informal sources such as personal contacts and "the grapevine". At least 12 SBUs were known to have access to corporate service departments which provided a formal mechanism for commissioning market studies, scanning patent specifications, technical reports, data banks, etc. These were rarely acknowledged as of strategic value. Proactive searching for opportunities and anticipation of threats on a continuing basis seemed more related to the managerial style of key executives than to the rigorous use of business/management information systems. From hereon it was possible to discern a pattern of responses which fitted well with the four-strategy schema of technology leaders, fast followers, late followers and niche exploiters.

4.142 Leaders

Executives in the few SBUs operating in close proximity to the leading edge of machine tool technology exhibited two sets of distinguishing characteristics: firstly, they were sensitive to maintaining secrecy and expressed concern about potential leakages through staff losses and 'loose talk'. This hindered research initially but became more relaxed as relationships developed. Secondly, they placed considerable value on 'being first' and were not content to merely keep abreast of competitors and technological advances. Product performance dominated their thinking and they were particularly adept at monitoring progress in related fields. One of the key competences which seemed to separate SBUs able to sustain their leadership position from temporary incumbents was an awareness of competitors in terms of their "total strategic capability" rather than solely from the narrow perspective of particular machine tool models.

The history of the machine tool industry is littered with examples of leaders and aspiring leaders who paid the penalty for their myopic "product-driven" view of competition. Some were first to the market with innovative machines and features, only to be leapfrogged unexpectedly by competitors offering improvements or outmanoeuvred by growth-minded competitors intent on establishing a global position. This partly accounts for the absence of UK-based leaders in the standard CNC turning and machining centre segments, where certain aggressive Japanese manufacturers have captured substantial market shares in Europe and North America by showing a better understanding of the coupling between technological and commercial leadership.

4.143 Fast followers

Followers are associated with predominantly reactive approaches to competitors, customers and technological change. Moreover, there is a tendency to use the term "follower" in a pejorative way due to connotations of immitation, risk-aversion and allowing their future to be largely determined externally. Such generalisations obscure the variety of reactive strategies along the continuum from fast to late follower and the differing demands placed on executives to process information.

Among the fast followers, for example, there were SBUs aspiring to leadership, some content to stay a 'comfortable distance' behind the leader and others slipping away. Executives in fast followers were found to have a good feel for their proximity to the frontier yet shared some of the leader's anxiety. As one executive explained: 'We know where the leader is going but they may be way out on timing and direction. We like to maintain a breathing space'. He used techno-commercial intelligence to pursue a "second-but-better" approach.

In contrast, most of the late followers were less conscious of their technological shortcomings and more preoccupied with 'responding to customer requirements'.

4.144 Late followers

An alarming ignorance of foreign competitors was found among some of the late followers and more laggardly niche-exploiters, often verging on apathy. This shortcoming is, of course, precisely why some of them are late followers and find themselves defending a diminishing niche or caught out by technological obsolescence. The most poignant example of their lax approach was the ease with which they dismissed foreign competitors as 'the Japanese' or 'the Germans' per se, as if they were a faceless enemy. For many of these SBUs, in mature products and markets, the strategic threat originates not only from manufacturers in the countries they mentioned but also from newly emerging producers (e.g. South Korea, Taiwan). This competitive factor was generally recognised, yet far from characterised and understood at the SBU level.

4.145 Niche exploiters

Outstanding detailed knowledge of foreign competitors' activities was identified among certain niche exploiters where a limited number of manufacturers compete for orders worldwide. This international oligopolistic market has on the one hand eased the task of keeping abreast of technological developments, yet on the other, orders are sporadic and considerable effort is necessary to monitor customer requirements. Examination of export ratios in these SBUs revealed the depressed state of the UK market, forcing them to become export-orientated and often accounting for over 70 per cent of total production to ensure survival. Some senior executives were spending up to 180 days per year overseas chasing orders. They had good awareness of competitors' order book status and product/process capabilities, and some had visited their plants. The highest incidence of inward licensing was found among these SBUs, many agreements resulting from early identification of opportunities and negotiation within a short time scale.

4.146 Reconciling the possession of market intelligence with position on the strategy continuum

The timely use of intelligence on competitor's capabilities was found to be an essential pre-requisite for sustaining and improving position on the strategy continuum of leadership/followership. Early possession of techno-commercial intelligence proved to be an important competitive advantage in that it assisted in the identification of licensing opportunities and allowed discretion in decision-making. Paradoxically, some executives across the full continuum of followers were as alert to environmental change as those found in leaders, yet their possession of intelligence was often inconsistent with their competitive position. Why, in the face of mounting evidence of technological obsolescence, had some internationally orientated executives apparently acted quickly and others delayed or failed to act at all? Why had certain strategic options, such as sourcing foreign technology, only received consideration during economic recession? Clearly, to progress further with analysis it was necessary to explore some of the softer areas associated with executive's boundary-spanning role and the identification of technological gaps.

4.15 The Nature of Technological Gaps

4.151 The tendency to focus on product gaps

Conceptually, the term "gap" is used in this research to describe the lag in technological capability relative to major competitors or the state-of-the-art. Thus a technological gap is a particular type of strategic problem.

Many executives in machine tool manufacturing SBUs found it difficult to articulate how they sensed technological gaps, offering 'gut feeling' and 'intuition' as initial explanations. Further probing related to specific events and developments proved to be a fruitful line of enquiry because it focussed attention on more tangible aspects of their operations and allowed triangulation. This revealed a confluence of factors, with competitor and customer activities featuring prominently in their reconstruction.

Some executives spoke of discovery that competitors were planning to launch a new model, investing in plant/equipment, recruiting a certain set of skills, sponsoring external research programmes, etc. Several had noted changing patterns of customer requirements and developments further down the derived demand chain or in other fields of engineering. Others seemed oblivious to events taking place in their immediate environment and relied mainly on the technical press. But by the time announcements reach the press, competitors had normally used the lead time to establish a temporary advantage.

One consistent pattern of scanning behaviour observed in this research was partitioning of the environment due to functional specialisation. It was noted, for example, that while Heads appeared to take a more rounded view of the machine tool industry, directors and senior managers responsible for the three main business functions (marketing, product engineering and production) tended to scan their own areas of interest. Nevertheless, there were substantial overlaps in their perceived domain and by far the most important of these was their common interest in the product. It was the balancing of these functional perspectives on the product that emerged as a key managerial task.

The prominent position accorded to the product in machine tools is to be expected since it provides the focus for buyer/seller interaction. Machine tool models also arouse a level of emotional affinity among people in the industry which may be likened to that encountered in more glamorous industries such as aerospace and motor vehicles. Over-emphasis on the product, however, has tended to encourage supply-side approaches to marketing in which product engineers have strongly influenced the definition of customer requirements. Other characteristics of this product-driven behaviour will be developed at various stages throughout this section.

Marketing, as a concept, has been slow to permeate machine tool manufacturing companies. As a function, it has assumed the tactical role of a commercial or sales activity, with the production function offering an equally short-term supporting role. In these circumstances, deteriorating performance has tended to find its initial explanation as a "product gap", often obscuring the emergence of a longer term strategic "technological gap". Recognising the nature of these gaps and the time scales involved in closing them was identified as an important component of strategic management capability.

4.152 Illustrative examples

Obsolescence of an SBUs core technology is an extreme case of technological deficiency and normally requires a turnaround strategy. For most machine tool SBUs, the problem was that of defining priorities within limited resources. They sought foreign technology to extend their product range or to fill gaps, to take them into a new area of technology quickly or to catch up. The following public statements by senior executives illustrate the motivation underlying three inward licence agreements:

> 'A tie-up with a Japanese manufacturer was the logical step as we didn't really have the resources to develop a range of suitable smaller stand-alone machines as well as our other commitments.'
> J. Dawson (1984), Manufacturing Systems Director, Kearney & Trecker Marwin.

> 'We could have developed our own (electrically-driven process robot) but it would have taken several years. We wanted one now!'
> C. Jansen (1982), Managing Director GEC Electrical Projects.

> 'We needed to get into a new field quickly, and we did not have the capability to design a machine ourselves.'
> A. Aldridge (1983), Managing Director Bridgeport Machines Division of Textron.

The last case of Bridgeport Machines deserves brief mention at this early stage of discussion because I regard them as a model of success in systematically utilising foreign machine tool technology to provide a platform for organic growth. This compares with the sad case of Wickman, whose fragmented and belated attempt to use foreign technology was insufficient to offset the combined effects of technological obsolescence and diminishing customer base in their core business.

(a) Bridgeport Machines is a US-owned company possessing a world-renowned name in milling machines. Up until the late 1970's they were predominantly a manufacturer of conventional turret machines with a strong customer base in toolrooms, jobbing shops and educational institutions. By repositioning themselves in the market through a £5 million investment programme involving the introduction of a range of horizontal CNC machining centres built under licence from Yasuda in Japan and vertical machining centres of their own design, they brought about a remarkable transformation from late follower to fast follower and aspiring leader over a five-year period.

(b) Wickman was one of several machine tool SBUs in the John Brown Group and generally regarded as the premier UK manufacturer of cam-operated multi-spindle automatic lathes. The seeds of Wickman's demise may be traced back to the 1970's, when they failed to adapt to the changing market, eventually finding themselves a prisoner in their own diminishing niche. Wickman attempted to get into CNC through an import agency, a design/build agreement with Taiyo Seiki in Japan and latterly, the acquisition of Olofsson in the US. None of these ventures was sufficient to save the company and it was divested in much-reduced form in 1983.

The case studies show that foreign technology played an important part in the fortunes of Bridgeport and Wickman. The former rebuilt their business by integrating product design and manufacturing technology into a coherent business strategy aimed at systematically closing the gap on their major Japanese rivals. The latter applied a series of piecemeal measures, best described as "too little, too late". Both companies entered the recession with a large part of their current business dependent on models in which the basic design had changed little over the post-war period. It was the dramatic downturn in the machine tool order cycle which triggered review of their product ranges and exposed the true state of maturity of their technology. The analysis will now turn to the order cycle and its effect on strategic development.

4.16 The Machine Tool Order Cycle

The phenomenon of the order cycle is well known in capital equipment industries and machine tool orders are frequently referred to as the "barometer" of the engineering and manufacturing industries. As shown in Figure 4, postwar cycles have typically exhibited 4-5 years peak to peak, with downturns often dipping below a level of 50-60 per cent of the previous peak. Production and sales tend to lag orders during the expansion phase and lead orders during recession, giving "order intake" a prominent role in conditioning optimism and short/medium term strategies.

Substantial evidence was uncovered in this research to show that executives closely monitor their order intake against trend data disseminated by the Machine Tool Trades Association. The speed with which deteriorating performance was detected varied across the different technological segments and depended on whether SBUs were offering standard or customised machines. Medium/high volume producers of standard or customised versions of standard machines, for example, needed to continuously monitor their market share and react quickly to changes in demand to avoid building up stocks. Producers of highly customised machines and flexible cells were less concerned with market share, and more preoccupied with the outcome of tendering procedures and dealing with the "lumpiness" of their order intake. In both cases, it was noted that a common feature of successful companies was the way they anticipated changing patterns of capital expenditure among their customer groups. Some were actively monitoring the conversion of enquiries into firm orders and conducted "lost order" analyses. Simultaneously, this enabled them to keep an eye on competitors and to separate false alarms from genuine downturns in the order cycle.

In most long-established SBUs, the first sign of incipient downturn triggered reversion to "coping strategies" based on the extrapolation of past experience, often accumulated over several order cycles. For SBUs operating in mature products and markets, this invariably meant retrenchment. Many executives spoke of 'conditioning themselves to feast and famine' and 'riding out the troughs'. One technical director in an SBU of a large machine tool group, referred to his group board's 'siege mentality' during recession. A main board director in the same group put forward the common defence of retrenchment policies of 'surviving where others had failed' and shedding staff at less than the industry rate as evidence of strategic management capability. Little thought had been given to how long the recession might last and the consequences of slow recovery.

What is perplexing about reliance on this recipe for survival is that very few executives had attempted to examine the vulnerability of their business to the recession they knew to be imminent. Their product/market scope was allowed to widen through customisation and importing arrangements, and it was not until the downturn was well underway that expectations were revised and attention focussed on the composition of product ranges, staffing levels and technological obsolescence.

Over the early part of the recession 1980-84, the validity of assumptions underlying conventional wisdom was questioned as anxiety surrounding the timing of the upturn increased. There was, for example, a temporary bottoming-out of orders towards the end of 1981, only to be followed by a further downturn in 1982. For some SBUs, the prolonged recession precipitated two rounds of redundancies and executives found it difficult to reconcile what they saw happening to their order book against more optimistic forecasts from the Confederation of British Industry, the Engineering Employers Federation and various forecasting units.

The magnitude of the downturn in the order cycle and its impact on machine tool companies is captured in the public statement by the Chairman of Butler Newall, part of the B Elliott Group:

> 'In 1980/81 the combined Butler (Halifax) and Newall (Peterborough and Keighley) businesses had an £80 million turnover capacity, and a £2 million order book. That is how bad it was' (Financial Times 2/9/87, p8).

4.17 Business Planning and Technological Issues

The cyclicality of machine tool orders has greatly influenced attitudes towards business planning systems. Formal planning was viewed with scepticism by senior executives in both UK-owned and US-owned SBUs and found to be conspicuously absent in independent companies. Beyond compilation of the annual budget found in all SBUs, it may be inferred from the general tenor of discussion that very few executives would have devoted time to medium/long term planning procedures without pressure to do so from their parent company. The following comments illustrate the range of opinions expressed by Heads of UK-owned SBUs about business planning:

> 'We have no medium/long-term plan written down. The current climate is changing so fast it's not worthwhile doing it'.
>
> 'Our parent company treat each business on its merits and seem to understand the problems we are facing ... I'm keen on the planning process but I don't have much faith in the result'.
>
> 'Planning is not relevant to our operations but we have prepared one-year, three and five-year plans for the bank'.
>
> 'We don't do formal medium/long term planning though it is claimed that we look ahead at plant and products. We ought to do more for communications reasons'.

It can be seen that planning was a contentious issue and every care was exercised in the research to avoid imposing personal values and tackling sensitive areas head on. This is an important methodological point because some executives had preconceptions of my academic position and equated this with "planning is good". Several gave mild apologies for them not formalising planning or abandoning it during recession.

Though business plans and product plans were frequently made available for inspection, no attempt was made to analyse procedures and content in detail. Instead, the aim was to probe some of the softer areas of objectives and corporate/SBU relationships, to gain a feel for the mechanism by which technological issues emerged and perceptions of their time scale.

Table 8 shows the findings on the business planning horizons adopted by a sub-set of 48 SBUs. The salient features of this data are the high proportion of UK-owned SBUs exhibiting an "order book" planning horizon and the higher incidence of medium/long term planning systems in US-owned SBUs. The latter point is to be expected: partly because of the corporate/business planning orientation in US multinationals and partly due to the desire of parent companies for accountability and control among their foreign subsidiaries.

Business planning in US-owned SBUs is characterised by the handing down of corporate policy statements and the use of manuals to ease consolidation. Top-down financial performance targets (e.g. return on capital, return on sales, liquidity) were typically accompanied by requests for bottom-up projections of how these might be achieved in terms of product/market strategies and capital investment. Beyond this, the pressure on Heads of SBU to meet corporate criteria, the

Table 8. Business Planning Time Horizons

Time Horizon (Years)	Number of SBUs UK-owned	US-owned	Total
Budget Period (1 Year)	31	17	48
"Order Book"	19	2	21
2	1	2	3
3	7	2	8
4	1	1	2
5	5	11	16
Long-term Outlook	1	5	5

N=48 SBUs

bureaucratisation of planning systems and the role of US vice-presidents carrying responsibility for UK operations, defies generalisation. In some SBUs, planning was found to be an intensive, highly iterative process requiring executives to attend lengthy meetings at US head office and to present their document before a committee. In others, the first document submitted appeared to be accepted with little feedback and it was almost as though UK operations were considered immaterial to parent company performance. The diversity of approaches is illustrated in the following comments:

> 'Since we were acquired by XYZ Corporation we have been inundated with various vice-presidents and corporate planners. They left me this tome (planning manual) on the last occasion. We're in for a tough time'.

> 'We have no hard written objectives. We try to achieve what we say we can do. We respond to Chicago to some extent but we have nothing beyond the formal budget. Chicago would show you piles of paperwork and computer projections'.

While most Heads of SBU, irrespective of ownership, bemoaned the coming of the annual planning cycle, the main source of pressure on them during recession may be attributed to the tightening of control systems. This varied considerably across all SBUs, taking the form of more active interest from group directors, shortening reporting periods, continuous updating of order projections and more frequent meetings. Cyclic downturn forced even the most undisciplined of SBUs to perform a "position audit", if not by name, and to examine their future direction. Though Heads claimed responsibility for the audit and subsequent interpretation of its findings, it was often difficult to trace who had handled the mechanics of compilation and the extent of technical inputs. Depending largely on their managerial style, about a quarter of the Heads interviewed had performed the whole audit themselves in a rather peremptory manner. Most had delegated the work to the various functions and acted as coordinator. Corporate planners and business development executives had made an active contribution in some SBUs which were divisions of larger groups, whereas in small and independent companies, the managing director or a small cabal of top managers had reviewed the competitive situation and produced little in the way of documentation.

The absence of formal planning systems did not necessarily mean that executives had no vision of the future, nor that they were failing to think and act strategically. It is interesting to note that while many claimed to be unable to plan beyond their current order book, this had not precluded them initiating development projects for new models and sanctioning capital investment in plant/equipment. Moreover, 48 per cent of SBUs in the "order book" time horizon category had committed themselves to inward licence agreements extending 5 to 10 years ahead!

4.18 Resistance to Change and the "Not Invented Here" Syndrome

The "not invented here" (NIH) syndrome is a colloquial description of the tendency of individuals and groups to reject external ideas which threaten their values, status and continuing stability. It is a well known, yet under-researched, aspect of behaviour in response to change and is often associated with low job mobility, complacency and employee's perceptions of the superiority of their own abilities.

In the recent history of machine tool manufacturing companies there is no shortage of anecdotal evidence to illustrate the dysfunctional effect of resistance to change. This ranged from open hostility against the introduction of new equipment and procedures, to more subtle, obstructive behaviour such as 'working to instructions from people who know best' and sitting on paperwork. In attempting to unravel instances of resistance to the introduction of foreign technology, I was well aware that these may appear in many guises and feelings vented on say an inward licensing decision, may well be manifestations of some other event or underlying discontent at the time.

After 1980/81, there was a marked softening of attitudes in some SBUs as orders declined and technological obsolescence became exposed by the recession. This is clearly illustrated in the following comments from two Heads of UK-owned SBUs who had quickly signed inward licence agreements as part of their survival strategy:

> 'Five years ago it would have been difficult, not so now. Any resistance soon evaporated... Most people felt relieved'.

> 'The attitude seemed to be: if it preserves jobs, then OK. You have to remember that at that stage we had already shed 280 people'.

These findings lend support to the "crisis-innovation" hypothesis that a large performance gap can induce a willingness to adopt radical change, despite the challenge to vested interests.

The two groups feeling the most anxiety of dislocation from the signing of inward licence agreements were, for different reasons, the horizontal group comprising the board of directors of the SBU and the vertical group representing the product engineering function. Heads possessing an engineering background found the decision particularly sensitive as they were seen to be reneging on earlier decisions in which they had participated and letting down their former colleagues. This personal discomfort, coupled with dependence on an external source of technology, heightened their perceived risk of failure and generated considerable anxiety. The reaction from product engineers was regarded by executives as predictable:

> 'It's a vote of no confidence in our ability to design and develop new machines'.

> 'It's the thin end of the wedge... our first step towards a "screw-driver" operation'.

As might be expected, the intensity of resistance was higher in SBUs using foreign technology to introduce extensive product/process diversification than in those merely filling a gap in the product range. Heated exchanges took place during the pre-signing period but the pattern of resistance varied in different SBUs as the implications unfolded. In two cases, product engineers behaved in an almost ritualistic way, offering their own hastily prepared design schemes to compete with the proposed licence. In these, and in two other cases, there was fragmented evidence of rallying support to mount an appeal to the Head, pointing out the contributions of product engineering to earlier successes and under-lining the danger in running down their activities.

It should be noted that in only four cases of inward licensing could it be stated with any acceptable confidence that political behaviour had delayed negotiation with the licensor. Each case resulted in the signing of an agreement. No attempt was made to estimate the cost of delays. A series of in-depth longitudinal studies would be necessary to take analysis further. This was considered beyond the scope of the current research. For longitudinal studies to be of strategic value in this area, it is believed that it is as important to examine covert behaviour as it is to map the more visible political posturing described here.

Negative feelings were found to persist long after initial licensing decisions had been taken and continued to work against implementation. While some Heads of SBU were expounding how the 'all-British mentality' and the NIH syndrome had been broken down, their middle managers and product engineers occupied pockets of resistance and could often see little good coming from agreements. Their difficulty in reconciling the tightening of constraints on internal design and development with the diversion of funds to acquire foreign technology surfaced in numerous conversations. The following comments capture parochial views of product innovation and the failure in some SBUs to communicate reasons for sourcing foreign technology to those who might feel the most hurt by it:

> 'When we took the licence for this equipment we were under the impression that it would open our eyes. It turned out that we are paying for the nameplate... The design is largely mechanical and obsolete'.
>
> 'The design is so simple, even a first year undergraduate could have handled it'.
>
> 'There's nothing special about what we've bought. All the licence has proved is that we have been doing the right things for years. Given equal resources, we could easily have come up with something better'.

The second comment above is a familiar one in the product design field. Once revealed, good aesthetic and functional aspects of design appear simple. The competitive edge often lies in being first-to-the-market and building a name for innovative products.

When the third comment above was put (anonymously) to the managing director, he said that he too once held the view that his company could design and build almost any item of machinery: 'We probably could have done, but not with commercial viability'. His mental concept of viability was cogently argued but he seldom shared his thoughts with colleagues and avoided any formal statement of objectives. Like many executives interviewed in this study, he involved himself extensively during the early stages of inward licensing and handled negotiation, yet neglected the post-decision implementation stage, leaving middle managers to maintain continuity towards ill-defined objectives.

Executives were normally reluctant to divulge their detailed aspirations and expectations for both internal and external consumption. This was particularly so for new product introductions and they were wary of inviting too much publicity to products derived from foreign sources of technology. 'High hopes' and 'encouraging prospects for future growth' were phrases selectively appearing in press releases, not only to maintain secrecy but also to avoid the risk of embarrassment at some later date should their predictions fail to materialise. Exceptions to this rule were found in five cases of "crisis innovation", three involving licence-based products and two involving products derived from parent company technology. The public statements accompanying these product introductions were as much designed to reassure employees that stability had been restored as they were to maintain customer confidence. DeVlieg, for example, on signing an inward licence agreement with Okuma in 1983, publicly announced their aim of producing 75-100 machining centres per year within two years, thereby doubling UK sales turnover to £15-20 million with the possibility of creating 100 additional jobs (Machinery 6/7/83, p6). DeVlieg's actual sales turnover for 1985/86 was £9 million and their workforce had remained almost unchanged.

Some of the most entrenched resistance to change was identified among Heads, engineering directors and product engineers in late follower SBUs which were heavy subscribers to the recipes outlined earlier. They frequently referred to past achievements and the shelving of ideas .... 'only to see them re-emerge embodied in competitor's machines offered under licence'. For years, incremental product innovation had been pursued on many fronts with tacit agreement of the Head with little medium/long term guidance from the sales function. It is to some extent amazing that in the changed competitive climate of the 1970's and 80's, such a free rein was allowed to build prototypes for their intrinsic technical interest with minimal market justification. Several of these SBUs faced collapse and five did so over the period of research. "Strategic technological issues" was not an expression they used and the notion of acquiring foreign technology to relieve their predicament beyond their comprehension. Only with new leadership, a substantial infusion of new staff and products could they have hoped to survive.

4.19 Executive's Perceptions of Corporate Constraints

4.191 Independent UK-owned SBUs

Indpendent machine tool manufacturing companies, representing 22 per cent of SBUs studied and many of them owner-managed, imposed considerable self-restraint on the financing and direction of new developments. Maintaining independence and not wishing to overstretch themselves were important factors in their highly personalised business strategies.

Most had attempted to update their existing product range through internal design and development. Some were struggling to keep abreast of technological change in diminishing market niches but were in no position to consider closing technological gaps by any means that impaired cash flow. Others were reluctantly forced to phase their way out of manufacturing and take on import agencies (factoring) in the medium/long term. A strong affiliation towards 'building machines' was found among independent companies, often so strong as to make inward licensing one of the few acceptable alternative strategies because, above all, it preserved their independent status and presence in manufacturing.

4.192 SBUs of UK engineering groups

SBUs which were machine tool divisions of larger UK-owned engineering and manufacturing groups (35 per cent of SBUs studied) had found themselves in the precarious position of poor relation in the corporate portfolio. Losses were tolerated by parent companies during downturns in the order cycle. When profits were generated with the upturn, cash was often taken out of the business, resulting in investment being run down to a level below the critical mass for ensuring continuing participation in particular product/market/technological segments.

Often the parent company itself was in financial trouble, resulting in ailing machine tool SBUs being sold off (e.g. John Brown Group and their Wickman and Webster & Bennett subsidiaries), or closed (e.g. Renold Group and J. Parkinson) or subject to management buy out (e.g. Redman Heenan Group and Fielding & Platt). SBUs of financially stronger parent companies often fared no better and many executives felt that they had long been candidates for divestment, pointing to other SBUs in the group which could always justify a better case for funding. Proposals to pursue certain strategic options involving capital investment frequently revealed perceptions of a serious mismatch between corporate expectations and what was considered achievable in individual SBUs. 'Unrealistic financial criteria' and 'lack of understanding of our business' were cited by executives who felt aggrieved when proposals had been turned down.

Discussion on the receptivity of group boards towards proposals invariably drifted towards rejections, yet the actual incidence of rejections was believed to be low. Evidence suggests that the timing and presentation of proposals were key factors in gaining approval, with corporate planners providing valuable assistance to some SBUs in interpreting 'the mood of the group board' and in 'framing proposals in an attractive way'. There appears to be some scope for further empirical investigation into this relationship.

The overall impression gained from interviews was on the one hand of group boards applying dispassionate scrutiny of proposals based on short-term financial performance and on the other of realisation that the diminishing size of some SBUs was becoming important. Group boards were found to be sensitive to their stock market position and executives in machine tool SBUs were clearly aware of this situation. Acceptability of particular options tended to hinge on the relative magnitude of capital payments, deferred payments (e.g. royalties) and the extent of equity arrangements. Import agencies and inward licence agreements therefore encountered a less tortuous route to approval than joint ventures and acquisitions.

4.193 SBUs of UK machine tool groups

SBUs which were divisions of UK-owned machine tool groups (13 per cent of SBUs studied) competed for resources as in the previous category but their role in overall group strategy required careful definition to avoid duplication and conflict. Evidence from the interviews suggests that manufacturing SBUs specialising in particular machine tool technologies had not achieved a good fit with SBUs set up to handle import agencies.

Corporate/SBU relationships were complex in this category of ownership due to mutual interest in the machine tool industry. Chairmen and executive Heads of SBU were often members of the group board, leading to intense rivalry and political behaviour related to resource allocation and their personal vision of the future. Although it was not possible to examine board room dynamics in a study of this kind, certain overt aspects of strategic adaptation provided prima facie evidence of simmering discontent at SBU level regarding constraints on product/market/technological scope.

Executives in manufacturing SBUs had accepted narrowly defined missions in the 1970s. The recession from 1980 onwards severely tested their survival as separate business entities and some were merged. Short-term priorities based on financial stringency were felt to penalise manufacturing more than importing activities, due to the differing magnitude and time scales of investment. Policy guidelines which perpetuated the manufacturing/importing demarcation were perceived to be inappropriate in the light of changing circumstances.

Replies to two questions were pertinent in this respect: What opportunities have you identified? and .... Can you give me an example of a recent proposal from your SBU which challenged group policy? These revealed the absence of group synergy and the failure of some ideas to emerge as proposals because of doubts surrounding receptivity at group level. Some executives and middle managers bitterly resented exclusion from importing and said that they were reluctant to waste time considering agencies if these would be handled by another SBU. Imported machines, it was argued, provide an important inward transfer of product technology and their home lay naturally in specialised manufacturing SBUs. As one Head of SBU put it: 'If we were a private company we would be allowed to supplement our income by selling complementary products'. Similarly, there was little incentive to importing SBUs to recommend that certain established agencies should be converted to manufacturing licences.

Policy guidelines for manufacturing SBUs regarding inward licensing, joint ventures and acquisitions were ill-defined. Financial criteria and market feasibility were important hurdles to be overcome but group boards tended to adopt a more "negotiated" approach to proposals from their SBUs. One group director spoke of 'taking each proposal on its merits' and another of 'not wishing to exclude options'. In reality, the absence of formal statements meant that executives at SBU level based their perception of acceptability on earlier precedents and the expected behaviour of key decision makers. In one group, for example, the acceptance/rejection of proposals clearly hinged on their endorsement by a powerful group director. He dominated technology strategy and seemed oblivious to the fact that his autocratic style had stifled bottom-up initiatives.

Towards the end of this research, the two major UK machine tool groups (600 Group and Elliott) had appointed new Chief Executives. Since then, each has expressed concern about their dependency on the vagaries of the machine tool business and declared an intention to diversify into other fields of engineering.

4.194 SBUs of US machine tool groups

UK subsidiaries of US parent companies (31 per cent of SBUs studied) exhibited many of the opportunities and constraints of the previous category, along with an additional set imposed by foreign ownership. Tight financial control pervaded all relationships between US parents and their subsidiaries. Beyond this, it was difficult to generalise on strategic behaviour because of policy constraints placed on sales territories, local design and development, sourcing of particular machine models and components. While some parents and subsidiaries had sought extensive interaction, others had grown away from each other and were tied largely by the financial link accompanying ownership. The intensity of relationships appeared to depend mainly on the contribution of UK and European operations to total group performance and executives' perceptions of technological dependency.

The more diversified the US parent company's product range, the stronger their belief in intra-group self-sufficiency. Import agencies, inward licensing, joint ventures and acquisitions normally only emerged as strategic options after a search within the group had failed to show that modifications of existing designs were unsatisfactory. Many UK executives felt that acquiring technology from outside the group would be considered 'a strategy of last resort' and a convincing case would be essential to secure parent company approval. Again, the discussion tended to centre on agencies and evidence was uncovered of several instances where formal proposals had not materialised.

One executive said that he had ....'looked at the possibility of importing a CNC grinder but it was not worth the hassle' with the US parent company. Others had 'sounded out' parent company interest and had been 'discouraged from proceeding further without the possibility of wider group participation'. This was particularly noticeable in the case of inward licensing opportunities. Closer examination of some of the agencies and licences which had not materialised showed that executives' definitions of "complementary" machines were often linked with their existing business and their main motivation was to offset the rapid downturn in sales of existing machines.

Executives in both US parent and UK subsidiaries had detected changing attitudes to external sources of technology in response to increasing competition and technological obsolescence. As one operations director put it: 'The single most important factor in current US/UK relationships is the recognition by our parent company that we now face a common set of competitors'.

4.195 Implications for strategic management

Serious questions have been raised surrounding Corporate/SBU relationships, particularly in the third category of ownership. Why do group board members intervene so frequently in the affairs of their SBUs? Part of the answer lies in the management style of some group directors who have a strong personal affinity for machine tools and feel the need for "hands on" control beyond financial reporting. Over time this has tended to breed Heads of SBU who are reactive and short on general management ability. A further explanation is of wider significance, related to economic conditions and the seige mentality. Having most of their SBUs in machine tools, extreme hostility in the environment has driven groups to centralise their structures temporarily. The dilemma facing these groups is that the speed and coordination associated with a centralised response clashes with the need to decentralise in order to comprehend environmental change.

From these four categories of ownership it can be seen that the range of strategic options actually evaluated was often quite narrow compared with the opportunities arising. Much subjective screening was carried out by individuals and in management meetings before feasibility studies were set up and formal proposals emerged, if at all. Such behaviour has implications for the "entrepreneurialism" and "organisational renewal" which are at the heart of strategic management capability.

The foregoing analysis and discussion has established the moderating effect of internal political behaviour on receptivity to foreign technology at two key levels: (a) at the functional level, mainly in the form of resistance to change among product engineers; and (b) at board level where the identification and closure of technological gaps is typically as much about the selection of a politically acceptable option as an economically viable one. On this evidence and on the earlier evidence presented on the international orientation of top management, the first working proposition is accepted.

4.2 RELATIVE STATUS OF THE PRODUCT ENGINEERING, MARKETING AND PRODUCTION FUNCTIONS

The second working proposition is:

> Technology strategy development in machine tool manufacturing companies is dominated by product engineering considerations to the relative neglect of marketing and manufacturing/production activities.

4.21 Antecedents to the Focus on Product Innovation

During the post-war period up to the late 1960's, machine tool manufacturers in the UK operated in a protected environment. There was little international competition and imports mainly comprised special purpose machines from the USA for which there was no local manufacturer. Profit margins were good compared with present standards. Order books were lengthy. Weak manufacturers could survive and in some cases, prosper.

Increasing intensity of competition in machine tools first appeared with the re-emergence of West German producers from about 1955 onwards. The challenge from West Germany was expected by manufacturers in the UK and when it came, it took the form of product innovation coupled with a carefully nurtured strategy to build a reputation for high quality precision engineering across a range of machines. Similarly, as other European producers returned to the scene, notably Italy, France and Austria, there was room for them to find a place in a steadily expanding world market by matching or improving on the product designs of existing competitors in both standard and customised machines.

Throughout the 1960's competition stimulated product innovation in traditional areas of mechanical engineering design and in the increasingly important field of control systems. Numerical control (NC) was still in its infancy and early adopters were largely confined to the aerospace industry. Some machine tool manufacturers in the UK had kept up with incremental NC developments but the scope for sales was restricted compared with the US.

Japanese manufacturers at this stage were rapidly increasing their machine tool production, though almost all output was for domestic consumption. Unlike the UK and US, design and development by leading Japanese manufacturers was concentrated on the application of NC to smaller general purpose machines of the type found in a wide variety of engineering and manufacturing plants.

Japanese manufacturers first entered the export market in a serious way in the early 1970's. By employing product/market strategies which focussed on a limited range of standard NC lathes and machining centres, they were able to exploit growing national capability in micro-electronics and build export volume on their strong domestic customer base.

Three techno-commercial factors contributed to the competitive edge enjoyed by Japanese manufacturers of standard machines :

(a) sustained investment in micro-electronics allowed them to dictate the pace of product innovation and model life cycles through computer numerical control systems;

(b) meticulous attention to product and process improvement created the de facto world standard for quality and reliability;

(c) high volumes reduced unit costs, thereby enhancing price competitiveness.

While Western commentators were referring to NC and later, CNC machines, as 'advanced technology' which would eventually trickle down from aerospace applications, the Japanese had begun to produce and distribute them as near-commodity products. This alone would probably have been sufficient to underpin an export-led market development campaign. The window of opportunity, however, finally opened in the late 1970's when the value of the Yen was at a low level relative to major world currencies and manufacturers in Europe and the US could not meet the surge in demand. Japanese manufacturers had built up stocks of standard CNC machines in what proved to be the growth segments, and sold them on price, product reliability and availability.

As the world entered recession in 1979/80, all Western countries felt the presence of Japanese manufacturers in general purpose CNC lathes and machining centres. By the mid-80's the top 5 Japanese companies had achieved production in these segments of at least an order of magnitude higher than found in the UK. Only in conventional (non-CNC) centre lathes and milling machines could it be said that UK manufacturers had comparable volumes. Unfortunately, these were not only declining segments under threat from more sophisticated CNC machines, these were also the target segments for low-cost producers from Taiwan and South Korea.

For most executives in the UK, the dilemma was whether to compete head-on in general purpose CNC machines or to join the well publicised "retreat" to customisation. As shown later in this sub-section, the former strategy was adopted by several SBUs with mixed success, while most pursued the latter strategy because it provided temporary respite from price competition and allowed them to fall back on traditional strengths in product engineering.

4.22 Observations on the Prevailing Socio-Economic Climate in the UK Machine Tool Industry in the 1980's

An holistic assessment of the contextual factors influencing organisational response to change provides a useful precursor to understanding the nature of internal power structures and cross-functional relationships between product engineering, marketing and manufacturing/production. Such an assessment is descriptive rather than analytical and is inevitably limited by the degree of access gained to key functions within the 54 SBUs covered by the research. Consequently, the observations made here refer to a sub-set of 39 SBUs. Any shortcomings with regard to comparability and lack of precision are considered acceptable when exploring broad issues of this kind.

The sharpest social division pervading machine tool manufacturing companies in the UK is the "staff" and "works" demarcation so widely documented by the labour process school of researchers. This is highly visible in remuneration systems whereby staff are paid a salary on a monthly basis and works employees "clock-in" to earn an hourly wage. The two groups are further differentiated by privileges and incentive schemes, the clothes they wear in the workplace and trade union membership. Such ubiquitous inequalities appear to be deeply embedded in the industrial culture of certain geographical regions.

Many manifestations of social division emerged during interviews and factory visits. My lasting impression relates to the bitterness and dejection surrounding the implementation of redundancy schemes. On the one hand, top management had clearly gone through a traumatic period as they attempted to scale down operations to a level they believed consistent with survival and future recovery. On the other, it was impossible to ignore extensive anecdotal evidence of management insensitivity and claims by works/production employees of inequitable treatment. Inspection of the case material set against sectoral data throws light on whether managers in machine tool manufacturing companies were even-handed in their approach to shedding labour :

(a) The Engineering Industry Training Board statutory returns for the years 1978 and 1984 set out in Table 45 show that while the total industry workforce was reduced by 60 per cent, the proportion of employees retained in most job grades marginally increased at the expense of operators. The greatest psychological impact was felt in the absolute numbers of operators and skilled craftsmen leaving the industry over the period (ie over 8700 and 10200 respectively).

(b) Comparing the trends in output and employment post-1979 presented in Table 46 offers evidence of the latter falling at a lesser rate than the former. Unfortunately, the picture of employment over the early 1980's is distorted due to short-time working, largely among production staff. In some cases this resulted in rising hourly production although annual output per employee had been reducing. The true position was further confused by SBUs taking on jobbing work or sub-contract machining to fill capacity and keep the workforce together.

The overall picture in the early 1980's was one of internal turbulence and low morale. There was widespread acceptance of the inevitability of cyclic downturn, yet when it came, everyone was ill-prepared for the consequences. Despite extensive trade union consultation, there was an apparent mismatch between senior management and workforce perceptions about the depth of crisis facing some SBUs, leading to prolonged uncertainty and instability. The greatest upheaval was observed in SBUs which simultaneously implemented redundancy schemes and seized the opportunity to radically change their mix of skills and product range required for the upturn. In contrast, executives who had merely "managed down" their operations could be said to have done so in an even-handed way but they often failed to tackle key human resource and capital investment issues.

While it was outside the scope of this research to analyse complex industrial relations processes in detail, it must be noted that both sides had perpetuated adversarial behaviour and there were few signs of a genuine search for common ground. Conflict in machine tool manufacturing companies never seemed far below the surface. Clearly, there is much work to be done by Government in creating an external industrial climate conducive to restoring competitiveness and by management in recognising the need for strategic change and preparing the ground for effective organisation development.

Informal discussions with executives in foreign multinational companies and importers of machine tools, especially those people who had previously worked for UK manufacturers, suggest that although industrial disharmony is not a particularly UK phenomenon, it is potentially more inhibiting to strategic change than in many foreign competitor's operations. Even allowing for national stereotyping, there is consensus of opinion about the lack of open-ness in UK machine tool manufacturers, rigid hierarchies and compartmentalisation, failure to respect manual skills and wider assertions associated with an anti-industrial society.

4.23 Relative Power and Status Systems

4.231 Product standardisation and customisation

Having briefly outlined aspects of the international competitive situation and social background relevant to the working proposition, it is now necessary to assess the extent to which internal power relationships have been shaped, and are shaped by, the nature of the work carried out in machine tool manufacturing SBUs. A useful starting point is to examine how SBUs deal with the conflicting requirements of product standardisation and customisation.

The level of customisation found in machine tools varies from minor modification of standard machines to highly specialised equipment tailored to the individual needs of large users. Though the national machine tool statistics separate out "unit construction" machines, the overall categorisation is unhelpful in detecting shifting patterns from standard to customised machines. Thus the main evidence of changes in product mix or product/market scope over time and their managerial implications must be gleaned from the adaptive behaviour of SBUs. This behaviour will be explored in the three operational contexts shown in Table 9.

Table 9. Breakdown of Sample by Type of Machine Production

Type of Machine Production	Percentage of SBUs Studied	Percentage of Total Sales for the Sample
Highly Customised Machines ("unit construction")	17	18
Standard Machines	26	34
Standard Machines and Customised Versions of Standard Machines	57	48
N=54 SBUs		

4.232 Producers of highly customised machines

SBUs producing highly customised machines were characterised by extensive day to day involvement of product engineers in production activities and their close coalition with sales engineers. Two key factors in the coalition were :

(a) the integrative role performed by proposals engineers, mainly located in the sales function and typically possessing the same background experience as both product and sales engineers (eg an apprenticeship, drawing office experience and several years service in the company);

(b) the central importance of product specifications as the vehicle for cross-functional communication.

Product engineers considered themselves to be the 'keepers of the specification'. Drawings were handed over to production less abruptly than in most SBUs with a distinct preference for 'liaison' rather than documentation. Scheduling the work flow was deemed to be important due to the "lumpiness" of order intake and uneven demand on resources. Involvement of production staff in compiling specifications and proposals depended on the size of orders and initiatives taken by individual production managers. When negotiating small orders, proposals engineers were considered to be sufficiently 'well-rounded' to handle cost/time estimates.

Large orders often resulted in the formation of a project team under the control of product engineering. This enhanced their status over sales and production, especially when conceptual and development work was necessary. Normally, however, machine design did not start from scratch and there was extensive reliance on modular construction and accumulated know-how. Manufacturing and assembly work was "craftsman-like" with considerable discretion exercised at all stages by supervisors and toolmakers. It is suggested that producers of highly customised machines provide the closest parallel to the much-admired Meister system in West Germany.

4.233 Producers of standard machines

Standard machines may be of the manual or CNC type and are normally produced in high volumes. Bridgeport, for example, celebrated UK production of their 40,000th Series One milling machine in 1985 with output of this single model peaking at 300 units per month in 1969/70. Cumulative volume and historical output rates, however, may be misleading: (a) due to order cycles, and (b) because models tend to be updated or superceded by more expensive CNC versions which are often 3 to 5 times more productive. The overall trend is one of shortening model life cycles, falling unit output and higher unit value.

Producers of standard machines operate in price sensitive segments of the world market where long term competitiveness depends on an effective sales distribution network and low cost production. Given these requirements it was not suprising to find that the status differential among the three main functions was much narrower. Product engineering appeared to carry marginally higher status than marketing/sales and manufacturing/production but there was evidence to tentatively suggest that volume and its cyclicality were important determinants in establishing the pecking order of the last two functions. In particular, whereas the power base of product engineering had remained fairly stable over time, the power bases of marketing and manufacturing fluctuated with order intake and production output respectively.

It is tempting to speculate that if SBUs increased their volume, then production or marketing might emerge as the dominant function. Two scenarios are worthy of brief mention here. It could be argued, for example, that as overall volume and batch sizes increase, production is the critical function. Alternatively, if flexible manufacturing systems are installed, production becomes almost based on a continuous process and marketing is the critical function. In the range of volumes found in standard machine tool manufacture, it is reasonable to conjecture that at least one element in the stability in Japanese companies may be due to a better functional balance and predictability of order input.

Based on the widely documented experience of Japanese manufacturers, the role of production engineers was expected to provide a key factor for success in standard machines. Yet in both UK and US-owned SBUs, they were few in number and their status was closely allied to that of the production function as a whole. Their influence was evident in some SBUs which had equipment dedicated to particular operations and linked by conveyors and gantries. Only 4 SBUs were using flow-line assembly. Most production engineers could outline their involvement in production planning/control systems, monitoring machine utilisation, quality initiatives and proposals for introducing advanced manufacturing technology. But theirs seemed a closed world and only exceptional individuals had raised their competence to meet the wider challenge of manufacturing systems engineering.

The salient organisational features of SBUs producing standard machines were: (a) their clear separation of the three main functions, often geographically, and (b) their greater formalisation of horizontal and vertical communication channels. Functional identification among staff at all levels was at its strongest. Top managers were more involved in new model introductions than in other SBUs, mainly because of the implications for resource allocation and potential for disruption of ongoing operations.

4.234 Producers of both standard machines and customised versions of standard machines.

These SBUs pose a set of intrinsically interesting research questions, mainly because the "retreat" to customisation has repercussions throughout the organisation. For some SBUs, particularly those in the low/medium volume range of production, difficulty in forecasting the mix of orders had caused problems for plant loading and severely tested the appropriateness of their service back-up and control systems in the changed circumstances. A familiar comment from sales managers was that they could estimate with reasonable accuracy how many orders might be placed over the next quarter but they had less confidence in naming which models would sell and how much customisation would be required.

The underlying trend towards customisation was frequently explained away by the need for flexibility and a search for added value. The questions not properly addressed by executives in SBUs primarily geared up to manufacture standard machines and drifting into customisation were : flexibility of what kind and at what cost?

Sales executives, in particular, had given little thought to defining the limits of product/market scope. Selectivity among orders was seldom an issue and most SBUs had succumbed to the temptation to accept any orders coming their way. When asked about the effects on production, there was good appreciation that long runs of standard machines are desirable for stability, yet general resignation that this was increasingly remote. Production executives tended to perceive flexibility in terms of workforce tasks or machine utilisation; whereas product engineers perceived it as modifications in machine design, customisation and new product introductions. Substantial evidence of trade-offs between variety in the product range and buying criteria such as price, delivery time and spares back-up was found in only 8 SBUs in this category.

Many instances were identified in the course of this research where top management failed to offer or communicate policy guidance on product mix, leaving lower levels of staff or interest groups to make their own interpretation of overall direction. Such inconsistencies tended to hide the true nature of performance gaps and their existence was usually discovered late on. Few had perceived a need to modify their internal information systems. This was largely because their costing and budgeting procedures were so broadly based that they could accommodate changes in product mix. Thus the profit contribution of individual products and product lines was obscured, resulting in inadequate monitoring and control.

One example of both inconsistency and lax control, involved a UK subsidiary of a US parent company. The managing director was newly appointed from outside the industry and later opted to double up as sales director. He asserted that company policy was to manufacture and sell standard machines from stock and that an exceptional case had to be made for customisation. This was later confirmed on visiting the US parent company, although some disappointment was expressed by a US vice-president about the diminishing scale of UK operations. UK staff were well aware that pressure was mounting to improve performance but there was lack of unanimity about how this should be brought about and little faith in strategies based on 'volume orientation'.

Product and sales engineers indicated that their priority increasingly lay in customisation, offering the forward order book as evidence of the (self-fulfilling) trend and pointing to the inordinately high stocks of standard machines and sub-assemblies which had been allowed to accumulate. Production staff appeared to play a passive role in decision-making and in one year stocks (£6.4 million) had almost equalled annual sales turnover (£7.9 million). As one senior engineer put it: 'Demand for our machines fell away but we kept making them', a comment also indicative of his contempt at the demise of the company. After three successive years of losses, amounting to £8 million, the SBU pulled out of manufacturing in the UK and the sales/service operation that remained took two years to run down stocks.

The apparent passivity of production staff noted in the above example is not an isolated case but it is insufficient as an explanation of behaviour across the 31 SBUs producing both standard machines and customised versions of standard machines. Production managers appeared quite adept at dealing with variety and uncertainty, though they readily conceded that it incurred hidden costs and involved devotion of a large part of their working day to "firefighting". Adverse effects on set-up times were the most commonly mentioned penalties of customisation. For evidence of firefighting, it was necessary to look no further than the series of interruptions taking place during my interviews in the production manager's office. Plant supervisors, sales engineers and others were continually seeking assistance for reasons such as progress chasing, breakdowns, shortages etc.

Many production managers were aware of the wider commercial issues and how they impinged on their job. But glaring inconsistencies passed unchallenged, the pressures and frustrations were absorbed within the production activity and seldom felt by top management. The plight of these production managers responding to customisation was not helped by abdication of responsibility at board level. One production director's idea of participation in decision-making was captured in his comment ....'they (sales and product engineering) tell me what they want, and I will make it'. And another director who felt that his ideas and criticisms would carry little weight as 'the name of the game is survival'. Very few executives in the manufacturing/production function saw product mix decisions as within their domain.

Product engineers emerged as the dominant group because it was they who initiated solutions to customer problems (ie 'the essence of customisation'). In the same way as sales managers appeared reluctant to turn away orders, product engineering managers were pleased to customise machines and production managers seldom refused to make them. To admit that a particular machine could not be made represented "loss of face", resulting in a willingness to improvise and be "all things to all men". In the event of being unable to handle certain parts of an order internally, it was relatively easy to revert to sub-contracting.

4.24 A Top-Down Perspective

4.241 The influence of top management education/experience

Consideration of the three types of machine production has shown that the status differential between product engineering and the other two functions of marketing/sales and manufacturing/production was the greatest in SBUs producing highly customised machines and the least in SBUs producing standard machines. Plausible explanations lie mainly in the perceived value of the expertise of product engineers and their

Table 10. Formal Higher Education of Heads of SBU

Higher Education	%
Graduates (Engineering/Scientific)	34
Corporate Membership of a Professional Engineering Institution via Non-Graduate Entry	26
Professional Qualification (Non-Engineering)	9
None	31
	100
N=54	

Table 11. Disciplinary Background of Heads of SBU

Discipline	%
Engineering : Mechanical/Electrical	34
Manufacturing/Production	23
General Engineering	20
Commercial/Sales	11
Finance/Accounting	8
Other	5
	100
N=54	

Table 12. Appointment Before Becoming Head of SBU

Heads of SBUs Producing :	M/S %	E/T %	P/M %	F %	Other %
Highly Customised Machines (N=9)	11	56	22	11	-
Standard Machines (N=14)	21	30	21	14	14
Standard and Customised Versions of Standard Machines (N=31)	19	39	26	3	13
All SBUs (N=54)	19	39	24	11	7

Key : M/S = Marketing/Sales, E/T = Engineering/Technical (product engineering), P/M = Production/Manufacturing, F = Finance control over specifications. Although no evidence was uncovered to indicate that the high status enjoyed by product engineers was reinforced by financial reward, there was widespread acceptance of the legitimacy of their position and that it carried prestige. It is now necessary to examine whether some of these overt manifestations of status and power are reinforced by the earlier education and functional background of Heads of SBU. The following observations relate to the data in Tables 10, 11 and 12 :

(a) Almost two thirds of Heads were engineering/science graduates or held equivalent qualifications accepted for corporate membership by the professional engineering institutions. When asked to describe their early career discipline, over half of the Heads interviewed named the traditional fields of mechanical or electrical engineering.

(b) The career progression of the majority of Heads was through the ranks of functional management, with the highest proportion appointed from the engineering/technical (product engineering) function. This data provides further evidence of the ascending importance of product engineering with increasing levels of customisation and suggests that hitherto, product engineering experience has offered the "fast track" for career progression in machine tools.

The most consistent pattern of responses, representing a high degree of unanimity at board level, was found among executives in SBUs producing customised machines. These executives were fairly rigid in their belief in the value of product engineering experience. This compares with responses from 4 SBUs producing standard machines in which executives showed consistency in citing marketing as the critical function for the future. Some executives in this cluster felt that the trend was well underway and they cited anecdotal evidence of recent appointments and job mobility (from product engineering to marketing) to support their views.

(c) Only 3 Heads had received formal education in business management and all were below the average age of 51 for this group. It should be noted that in the late 80's the current generation of Heads were educated before business/commercial topics appeared as an integral part of the engineering curriculum and when business education in the UK was in its infancy. A similar situation was found among functional directors. Some executives had attended self-selected conferences, short courses and training programmes, but their choice tended to be knowledge-based rather than skills-based and time away from the office was an important determinant of participation. This suggests a critical deficiency in the preparation of functional directors and managers for the wider role of general management.

(d) The affinity of Heads towards their previous function created difficulties in several SBUs : firstly, because they had failed to assume the general management role; and secondly, due to the discomfort imposed on the director taking up the functional appointment vacated by the Head. As one engineering director in this position put it : 'Sometimes we feel the "most favoured" department .... most times we resent the interference'. And from another director : 'He's doing too much second guessing at the moment .... we each telephoned the same customer about the same thing last week'. Anecdotal evidence of friction generated by this duplication of effort was mainly related to the early 80's, when some Heads adopted a centralised, "hands on" approach to crisis management.

(e) When Heads were asked what skills they envisaged their SBU would require in the future, by far the most common response was that of "systems capability". This was not surprising since systems integration was one of the major talking points in the machine tool industry in the 1980's. Some executives were merely repeating slogans but it was relatively easy to separate out those who were seriously pursuing systems capability from those whose ambitious rhetoric failed to match the limited resources at their disposal and whose views often conflicted with their senior colleagues. The most important finding from this question, however, was the overwhelming support for systems capability perceived as falling largely within the domain of product engineering.

4.242 Cross-functional interaction at board level

A useful indirect indication of power relationships may be gained from examining the level of day to day contact board members have with the various functions. This interaction is captured in Table 13 and the main observations may be summarised as follows :

(a) Heads of SBU claim the most frequent interaction and manufacturing/production directors the least.

(b) Among the functional directors, marketing/sales directors sought

Table 13. Cross-Functional Interaction at Board Level

What level of day-to-day contact do you have with the various functions ?

	V Infrequent (%)	Infrequent (%)	Regularly (%)	Frequent (%)	V Frequent (%)
Head of SBU with: (N=39)					
M/S Function	-	-	18	35	47
P/M Function	-	-	16	36	48
E/T Function	-	-	12	39	49
F Function	-	4	21	41	34
M/S Director with: (N=32)					
Head of SBU	-	-	11	39	50
P/M Function	-	12	53	25	10
E/T Function	-	-	29	43	28
F Function	-	8	51	22	19
P/M Director with: (N=28)					
Head of SBU	-	4	65	24	7
M/S Function	-	10	53	26	11
E/T Function	-	5	24	44	27
F Function	4	16	46	24	10
E/T Director with: (N=33)					
Head of SBU	-	-	27	31	42
M/S Director	-	4	34	21	21
P/M Director	-	-	53	22	25
F Director	6	22	48	15	10

Key : M/S = Marketing/Sales, E/T = Engineering/Technical (product engineering), P/M = Production/Manufacturing, F = Finance
Note : Finance Directors were not interviewed

greatest interaction with the Head and manufacturing/production directors least with the Head. The frequency of interaction with the finance function was comparatively low, though some executives said that the content of meetings was often more important than frequency.

(c) Overall, the most frequent interaction on a day to day basis was sought with the engineering/technical (product engineering) function. Probing the nature of this contact more deeply revealed that board level interaction was significantly exceeded by middle/lower management interaction. Evidence of the latter is to be found in product engineering membership of important committees - a factor which will be pursued later in the context of achieving "systems" benefits and when examining the key players in technology transfer.

4.243 Top Manager's perception of relative status

Heads of SBU and directors responsible for the three main functions were asked to comment on the status of marketing/sales and production/ manufacturing relative to the engineering/technical (product engineering) function. Expressing this as an index in which product engineering provided a base line of 100, the results are presented in Table 14 for the three types of machine production. The following observations on the data are pertinent to the proposition under investigation:

(a) There was a high degree of consistency in the responses from Heads of SBU in their portrayal of equal status across functions. These

Table 14. Executive's Perceptions of the Overall Status of Marketing/Sales and Production/Manufacturing Relative to the Engineering/Technical Function for Three Types of Machine Production

Function	Mean Status Ratings* by Senior Executives Head of SBU N=39	M/S Directors N=32	E/T Directors N=33	P/M Directors N=28
Customised Machines:				
E/T Function	100	100	100	100
M/S Function	98 (SD=2.3)	91 (SD=11.3)	89 (SD=5.0)	93 (SD=10.1)
P/M Function	96 (SD=4.2)	89 (SD-9.2)	93 (SD=6.1)	83 (SD=12.2)
Standard Machines:				
E/T Function	100	100	100	100
M/S Function	100 (SD=4.1)	98 (SD=7.4)	92 (SD=6.5)	96 (SD=8.1)
P/M Function	98 (SD=3.2)	96 (SD=8.1)	96 (SD=6.1)	90 (SD=10.7)
Standard Machines and Customised Versions of Standard Machines:				
E/T Function	100	100	100	100
M/S Function	96 (SD=3.9)	90 (SD=11.1)	92 (SD=5.2)	93 (SD=10.1)
P/M Function	98 (SD=4.2)	92 (SD=9.1)	98 (SD=4.3)	81 (SD=14.2)

* Index based on E/T (Product Engineering) = 100.

Key: M/S = Marketing/Sales, E/T = Engineering/Technical (product engineering), P/M = Production/Manufacturing

findings should be interpreted with caution as it is difficult to know whether they represent true feelings or an attempt to convey the "public face" impression of even-handedness in their approach to general management and career development. Functional status was found to be a sensitive political issue with some Heads, typified by responses such as ....'there is no obvious fast track to the top in this company', ...'we try to avoid favouritism', and ....'an obvious bias would make it difficult for us to recruit and retain good people'. Nevertheless, there is sufficient anecdotal evidence and insights gained during unguarded moments in the interviews to speculate that a greater spread of responses might have been elicited from Heads had closer research relationships developed over time.

(b) Production/manufacturing directors' perceptions of their own status was markedly lower across all types of machine production. The mean score of 81 and wide spread (SD=14.2) for SBUs manufacturing both standard and customised machines provided the worst case. This changed little over the course of the research and may be mainly attributed to the firefighting, low morale and social divisions highlighted earlier in this section.

4.25 Resource Allocation

4.251 A confused picture of cross-functional resource allocation

An understanding of the process and outcome of resource allocation is generally regarded as providing a guide to patterns of power and influence within organisations.

Initially, my research in this area centred on a proposition based on the "zero-sum" approach, involving winners (product engineering?) and losers (sales and production?). It then shifted towards cash being allocated sequentially to product, process and sales activities. The underlying reason for this change in proposition, and occasional oscillation between the two, was that while most SBUs had committed cash to projects at the acceptance stage, subsequent reviews often trimmed back original budgets, leaving the later stages severely depleted. Many projects were shelved or downscaled during the course of my research, suggesting that projects with a life of up to 3 years are extremely vulnerable. Thus the timing of project initiation and commercialisation was found to be an important variable in determining cumulative amounts of expenditure and how resources are allocated across various activities.

Ascertaining even a crude indication of resource allocation across functions was fraught with difficulty. This is partly because statements by executives were often vague or misleading, and partly due to industry surveys and press reports that were impossible to reconcile with the situation as I found it. Two examples illustrate the problem facing outsiders attempting to make sensible interpretations :

(a) One managing director was reported in the press as claiming that his SBU had invested £700,000 on developing a new model. This was clearly inconsistent with the potential market for the machine envisaged by the marketing director and with company payback criteria. The reported figure was later explained away as 'misinterpretation of the word "several" .... the true figure being closer to £400,000'!

(b) Another managing director had made a public statement via a press release that his SBU's expenditure on R&D would be running at over 4 per cent of sales turnover in the coming year. Closer inspection of historical expenditure on R&D within this SBU revealed not only a relatively low level of projected sales but also that a moratorium had been imposed on R&D during the previous two years. Almost all of the current expenditure could be attributed to "defensive" R&D.

There is no legal requirement for the disclosure of R&D expenditure in financial statements and even if this were mandatory, it would be a poor indicator of "technical effort" in machine tools. This is because technical effort is spread over research, design, development, applications engineering etc., and there are unaccounted inputs from component suppliers and customers. Best estimates of technical effort were as follows :

(a) Technical effort typically represents about 5-10 per cent of sales turnover and involves 10-15 per cent of employees. These proportions could be higher in SBUs producing highly customised machines and lower in SBUs producing standard general purpose machines.

(b) The division of technical effort between product and process only emerged as a discussion point in 4 SBUs producing highly customised machines, 5 SBUs producing standard machines and 11 producing both standard and customised versions of standard machines. The consensus of opinion was that process-related activities typically account for up to 25-30 per cent of total expenditure on technical effort prior to major product introductions, settling down below 15 per cent under normal conditions.

4.252 Product engineering

Most Heads of SBU approached resource allocations to product engineering with some trepidation. Projects were becoming more risky for those wishing to maintain their position as leaders or fast followers and the mix of human and physical resources was changing rapidly. Some changes reinforced the existing power structure, while others challenged it.

The product engineering function of the 1960's and 70's, for example, typically comprised: (a) a handful of key designers involved in conceptual and layout work, surrounded by a team of detail draughtsmen, and (b) development groups employing specialists working on prototype machines, sub-systems and applications. The skills profile of the product engineering function of the 1980's shifted on the one hand towards specialists in electronics and software, and on the other towards multidisciplinary skills associated with computer-aided design (CAD) and systems engineering. There are signs of a rising scientific and technological elite related to these new skills and a shortage of software engineers in the late 1980's led to higher salaries. This tended to enhance the standing of product engineering and several instances were recorded of machine tool SBUs "poaching" software engineers from each other or losing them to companies outside the machine tool industry where prospects were more attractive. Product engineering managers faced the dilemma of whether to invest in training and build up an in-house team or to seek an alliance with a software house.

The adoption of CAD provides a topic worthy of empirical research in its own right and is beyond the scope of this research. It is sufficient here to note that CAD is reshaping communication systems and cross-functional behaviour. In both UK and US-owned SBUs it was found that CAD was initially seen as a product engineering investment and attention focussed on localised factors such as building up a design database, staff retraining and stemming job losses. At a later stage of implementation, when the benefits of a common CAD/CAM database emerged, it was observed that emphasis switched to production engineers, process planners, tooling engineers and others gaining earlier and freer access to product information. This trend towards information sharing represents gradual erosion of an historical product engineering power base.

4.253 Manufacturing/Production

Unlike product engineering, the manufacturing/production function has always had to contend with capital investment appraisal, though there is continuing debate about the inadequacies of appraisal methods and what criteria constitute successful implementation. Over 70 per cent of Heads said that their manufacturing processes had become more capital intensive over the previous decade. Surprisingly, few Heads reported a shortage of funding for the new equipment. During the good years, purchases of equipment had been funded out of profits. Invariably, these were for stand-alone general purpose equipment to facilitate the machining requirements of individual new model programmes rather than as part of an integrated effort to improve productivity or expand capacity.

When asked about the applicability of advanced manufacturing technology to their type and scale of operations, executives frequently cited low volume throughput and long payback periods as a powerful argument against installing flexible manufacturing cells and in favour of general purpose equipment. This may be partly attributed to: (a) short-term objectives imposed by parent companies on some SBUs, and (b) to the difficulty in evaluating integrative technologies in which the cost of a particular investment may be nominally allocated to one function and the benefits emerge in other functions and collectively. The last theme will be taken up again later in the context of systems benefits.

4.254 Marketing/Sales

The historically low position of marketing/sales in the functional pecking order mainly reflects its inherent lack of professional skills and failure to bring stability to the flow of orders. Accurate identification and anticipation of customer requirements, increasing volume and improved order predictability, were recurring aspects of internal stability emerging in this research as valued by both the product engineering and manufacturing/production functions. Some marketing directors attempted to convey the impression of their SBU becoming more 'market orientated' or 'responsive to customer needs'. These assertions often appeared hollow in the light of reluctance to allocate resources to market research and poor awareness of product/market segmentation and positioning. Under pressure to maintain short-term profitability, most SBUs pursued productivity improvements to preserve margins in preference to aggressive volume-based strategies such as market development and market penetration.

At the extreme ends of the machine tool production continuum (ie highly customised machines and standard machines), it was expected that the role of marketing and the allocation of resources would be much clearer than within those SBUs in the middle. The evidence suggests that marketing is vaguely articulated as "commercial/sales engineering" in customised machines and "sales/marketing" in standard machines. One SBU producing standard machines had separated the role of sales and marketing at board level in recognition of the wider and longer term responsibilities associated with marketing. This exceptional marketing director had earned the respect of his colleagues in sales and brought both order and vision to his SBU's activities. In contrast, sales directors in several other SBUs had, over the course of this research, changed their job titles to sales/marketing with little evidence of a change in behaviour or a better appreciation of the need to allocate resources to market position. It is difficult to envisage the marketing/sales function improving its internal status and gaining a greater say in resource allocation without some form of intervention involving marketing education, training and development.

4.26 The Urgent Need for Strategic Re-Orientation

The foregoing analysis has shown that the ascending status of product engineers is associated with increasing levels of customisation and may be reinforced by the earlier education/experience of top managers. Existence of the functional imbalance implied in the working proposition has, therefore, been established and existing power relationships shown to impede strategic re-orientation in-line with the changing nature of international competition in machine tools.

Since the late 1970's, strategic re-orientation has clearly meant a shift away from the long-standing emphasis on product engineering-led innovation towards a business strategy which embraces the marketing and manufacturing dimensions. In this respect, re-orientation is as much about raising absolute levels of functional capability as it is about reducing status differentials with product engineering. Manufacturers of standard general purpose machine tools in the UK were among the first to feel the full intensity of Japanese competition and some have responded by implementing strategies which recognise the importance of both marketing and manufacturing capability as key success factors. Retreating towards customisation does not provide a safe haven from competition. Unwillingness and/or inability to change, not only suggests continuing exclusion from critical sources of competitive advantage but also represents a serious threat to survival during the next economic downturn.

4.3 SOURCES OF SUSTAINABLE COMPETITIVE ADVANTAGE

The third working proposition is :

> Failure to manage internal relationships (eg the coupling between product and process) and external exchange relationships (eg interaction with sub-contractors, component suppliers and customers) as an integrated system involves sacrifice of sustainable competitive advantage.

4.31 An Integrative Approach

The traditional stance on product design and manufacturing/production process technology is that the former is about achieving product differentiation through aesthetics and performance to specification, while the latter has tended to focus on output and cost reduction. More recently, burgeoning interest in computer integrated manufacture has emphasised "systems" benefits in two important ways: firstly, by promoting a stronger coupling between product and process through the concept of "design for economic manufacture or makeability"; and secondly, by widening the debate to include strategic alliances with sub-contractors, component suppliers and customers. This integrative approach suggests that exploration of the way machine tool manufacturers manage internal and external linkages will reveal the nature of competitive advantages and their potential for sustainability.

4.32 The Coupling Between Product and Process

4.321 Modular construction

Modular construction is at the heart of product/process simplification and offers potential for the cost-efficient production of both standard and highly customised machines. Two disparate examples, extracted from the case studies, illustrate what can be achieved by combining modular design with a fundamental re-think of market requirements and manufacturing support:

(a) After many years of customising a wide range of machine tools, a UK manufacturer, Wadkin, took the bold decision in 1978/79 to reverse the trend and focus their efforts on standard CNC machining centres, starting with a vertical model incorporating a single bought-in proprietary control system. Wadkin's challenge lay in producing machining centres to a unit cost, which by the end of 1983 was clearly a matter of being competitive with the leading Japanese importers who had claimed 53 per cent of all machining centres sold in the UK.

Wadkin recognised early on that product rationalisation and cost cutting exercises eventually reach a threshold beyond which it is difficult to make worthwhile savings without major redesign. Their response was the "unit-build" concept, not merely the breakdown of an existing machine into modules but the integration of rigorous testing, simulation and assembly procedures. By progressively testing sub-assemblies, Wadkin eliminated lengthy fault-finding work on finished machines prior to delivery and vastly improved in-service reliability. Specifically, they claimed that assembly lead times had been reduced from 20 weeks to 20 days and first year warranty costs reduced by a factor of 4.

(b) The US Bodine Corporation is an outstanding example of good practice in the field of automated assembly equipment. It is a family owned/managed company with licensees in the UK and Japan. Bodine has excelled in the US by combining customer orientation with product/market/technology definition. Their distinctive competence resides in applications know-how for the high-speed (40-50 parts per minute) synchronous assembly of small parts for key customers such as Black & Decker, 3M and GM Delco. Access to multinational customers is an important competitive advantage available to Bodine's licensees.

Bodine's technology centres on the manufacture of basic modules to achieve an in-line chassis configuration, itself the result of an inward licensing arrangement with AG Russell in 1963. They operate a policy of targeting orders to suit their particular type of assembly machine but this has not prevented them from moving into flexible assembly systems involving sophisticated computer monitoring and control techniques.

Market focus and modular construction were important ingredients leading to internally consistent strategies in Wadkin and Bodine. Such clarity, however, was seldom found among the many SBUs increasingly willing to customise standard machines. As indicated in the discussion under the previous proposition, product engineering tends to occupy a pivotal position between marketing and production. On the one hand, modular construction and interchangeability of components may be used to justify variety in the product range; but on the other, this must be supported by sustained investment in advanced equipment and the appropriate managerial control systems to cope with the potential disarray imposed by unpredictability of the order mix.

Modular construction was widely and successfully practised by producers of highly customised machines. By shifting some of the responsibility for production backwards into the design activity, significant progress had been made in the areas of product and process simplification. Evidence was found of standard mechanical modules and to a lesser extent, electrical modules or sub-assemblies, facilitating interchangeability and allowing customisation to be put back to the later stages of production. Such advantages were measurable in terms of reduced lead times, stock-holding and work-in-progress; reduced labour costs, inspection and commissioning times etc. These were, in turn, translated into customer benefits in the market place as competitive price and delivery; and most importantly, as improved product reliability.

4.322 Value engineering and value analysis

The techniques of value engineering and value analysis involve cost reduction on new and existing machines respectively without loss of value to the customer, while simultaneously offering the opportunity to achieve a closer coupling between product and process.

Whether machine tool designers consciously build-in value and consider the "makeability" of their designs is not easy to assess in a general way. Designers quickly asserted their claim to value engineering as an integral part of their thinking processes at the conceptual design stage for new machines. Some machines were originally conceived, and hence value-engineered,many years prior to the period of investigation, thereby constraining product/process innovation embodied in current models. It was noticeable in several machines how incremental changes had led to an assembly of parts with only tenuous visual connection. This was typically due to the incorporation of proprietary components from different suppliers over the years and the personal inclination of designers making the modifications. Other machines had undergone major redesign or were completely new configurations. And yet others were the result of value engineering carried out in foreign licensor and parent companies.

In SBUs producing highly customised machines and those with low volume production, greater weight was attributed to 'up front' value engineering than 'ongoing' value analysis. As one senior design engineer described the situation in his SBU: 'We put more effort into the end result than into getting costs down .... We build the best machine in the time available'. On receiving the order, priorities were discussed at an internal meeting of all interested parties, followed by an allocation of man-hours to each task to build up a total cost. This reduced the risk of cost/time over-runs and allowed for contigencies, but gave little incentive to improve designs and reduce future costs.

Value analysis of existing machines through redesign, appraising bought-in materials and components, and searching for more efficient methods of production was found in varying degrees in most SBUs. It was expected, a priori that the incidence of systematic application of the technique would be higher among larger SBUs producing standard machines in the medium/high volume range. This was partly based on the assumption that these SBUs employ more production engineers who would exploit opportunities to reduce costs over a larger volume. In practice, greater interest in value analysis was found in larger SBUs but implementation was fragmented and tracing the locus of responsibility was particularly difficult.

There was little evidence to suggest that producers of standard machines were more rigorous in their application and commitment than those devoting an increasing proportion of output to customised versions. The normative element in the assumption was acknowledged by executives and they were conscious of their shortcomings, yet some kind of inertial phenomenon seemed to prevent them from operationalising ideas they knew to be beneficial. Often this was rationalised, either by turning discussion to other issues which had temporarily diverted their attention or dismissing value analysis as '....we can't do everything'. One engineering director, for example, said that formalised approaches to value analysis had been a victim of earlier retrenchment and current priorities lay in 'working capital reduction through improvement of lead times and stockholding'. Customisation was at an increasingly high level and he regarded costing as 'a nightmare'.

The main triggers for value analysis were price competition on particular models or an edict from top management to reduce overall costs in response to the recession. Engineers in several larger SBUs had attended short training courses and this had rekindled enthusiasm for value analysis. The formation of multidisciplinary teams was claimed by some executives but further investigation often revealed that tasks had been delegated to design engineers, production engineers and buyers either as part of their functional role or under the auspices of a new product committee. Surprisingly, few executives could give spontaneous answers to questions relating to the areas offering most scope for cost reduction within their control. Minor improvements such as waste reduction, parts consolidation, better use of jigs and fixtures, and 'squeezing a better deal from suppliers and sub-contractors' were common replies. Simplification of work flows, leading to the regrouping of machines and the introduction of advanced manufacturing technology, seldom emerged as more radical cost-reducing strategies.

One of the least publicised aspects of value analysis/engineering is the contribution of "reverse engineering". From 39 useable responses, executives in over half the SBUs felt that acquiring and stripping down competitor's machines was prevalent in the industry. Two thirds of these said that Japanese and US manufacturers of standard general purpose machines were the most active. Only 5 executives in UK-owned SBUs admitted doing it and a further 6 said they would like to do it but that it would be too large an investment for them. Executives in 4 US-owned SBUs said that they left reverse engineering to their parent company. Most attempts to copy and improve on competitor's designs were based on information gleaned from leaflets, manuals, trade shows and poaching staff. Only two examples of blatant copying were discovered.

4.323 Experience curves

A popular belief in the UK machine tool industry is that the volume orientation of Japanese manufactures is a major factor underlying their success, particularly in standard CNC machines. Exploring attitudes to experience curves, therefore, provided an indication of the strategic importance attached to unit cost reduction with cumulative volume and a useful perspective on the exploitation of competitive advantages embodied in manufacturing processes. Of the 46 useable responses, 36 executives (78 per cent) showed more than a passing interest in experience curves and 25 (54 per cent) said that they were relevant to their operations. The most frequent replies may be paraphrased as: 'We know they exist but we do not apply them scientifically' and ....'We know we incur losses on the first few machines and soon reach the flat portion of the curve'.

Many executives tended to express unit cost reductions for new models in terms of the number of batches of machines. In one SBU producing high volume standard machines, for example, it was said that rapid cost reductions had been achieved on a new model over the first two batches of 50 machines, followed by a flattening out of the cost curve for the third and fourth batches. Several executives referred to the effects of "learning" on the reduction of hours rather than total "experience", with one executive claiming a 50 per cent reduction in assembly time for a new CNC model after producing the first 10 machines. Very little evidence was found of the classical way of relating percentage unit cost reductions to the doubling of cumulative volume.

While some executives had good intuitive understanding of the benefits from tracking unit costs, they had abandoned doing it for a range of practical reasons:

> 'I have tried to conduct an historical analysis. We have flow-line production and should know. I found no useful data and had difficulty in determining how overheads had been allocated.

> Prices have been adjusted according to the industry index. About 15 to 20 models have common components and this complicated the issue'.
>
> 'Our measuring systems are not sophisticated enough to do it. I know that our 25th machine is not the same as the first 2 or 3, both in cost and features'.
>
> 'We know about the phenomenon but have not attempted to measure cost reductions. We recently stopped making certain machines temporarily .... We normally produce them in batches of 20-30, some to order, some for stock. We ran out of stock and had to make a few in a corner of the workshop. The costs soared'.
>
> 'Experience curves have been considered. The company once said of a vertical machine: "We could make 40 per year and the unit costs will be so low it won't be true". We sold one machine in 18 months'.

The third comment above is partially indicative of the dislocation in production processes felt by many SBUs during the recession. Unfortunately, product rationalisation programmes, concern for break-even volumes and increasing levels of customisation tended to take precedent over longer term views of cost competitiveness and introduced a degree of circularity into discussions. The fourth comment is by no means an isolated example of a product engineering-led SBU in which the sales staff were left to find a market for the machine and production staff awaited volume that never materialised.

Cost reduction strategies were pursued with varying degrees of vigour in all SBUs. Executives were well aware of volume-related cost behaviour in the case of standard machines but achieving cost leadership was not regarded as a realistic possibility. Many executives were content to reduce cost differentials to a level where they could 'live with the Japanese'. The need to 'design and build to a cost' was equally appreciated in SBUs willing to customise machines. A major problem facing customisers was that they were increasingly caught between the inadequacies of their internal systems, particularly costing and production control, and the unwillingness of customers to pay premia on specials.

4.324 Quality management

Total quality management was declared by most executives to be a top priority for the 1980's. This was mainly in response to: (a) heightened awareness of competitor's achievements, (b) the demands placed on SBUs for better dimensional accuracy and finish due to the rapid diffusion of CNC technology, and (c) the need to secure approval to BS 5750 and ISO 9000. Indeed, all SBUs had initiated some form of quality improvement programme involving staff training, the purchase of sophisticated equipment and adoption of new procedures.

The most visible commitment was found in 3 large SBUs which had created separate representation for quality management at board level, though it was too early to assess their overall impact on cultural change. The longest serving quality director referred to 'cost re-distribution' as a source of improvement leading to customer satisfaction. By this he meant that cost savings of the order 5-8 per cent of total manufacturing cost had been made by virtually eliminating rectification costs incurred during final assembly and commissioning, with some of these savings being re-invested in "preventative" measures. On the negative side, he expressed disappointment with his company's consultative process: 'We tried quality circles ....but after 12 months or so, they (a team of middle/junior managers and shop floor workers) didn't feel they wanted to continue, and no-one wanted to pick it up'. The precise reason for abandoning quality circles in this case is unclear. In several other cases, interest in quality circles or productivity teams waned over time mainly because they became a 'talking shop rather than action orientated' due to poor organisation and failure to devolve responsibility for problem solving.

Another quality director put forward the view that superior product quality had offered a clear competitive advantage to Japanese machine tool manufacturers in the 1980's, coupled with the assertion that differentials would soon be eroded to the point of quality becoming almost a "given" on the list of customer buying criteria. This seems a plausible prognosis in the long term. However, it should be noted that time scales for catching up may depend as much on complementary changes in national supply infrastructure as on internal attitudes to quality management. As will be shown later, the evolution of a closely knit supply infrastructure in Japan facilitated their exploitation of quality as a differentiator and gave them significant "first mover" advantages, in which they continue to invest.

Many production managers were proud of their achievements, offering documentary evidence of lower defect rates, meeting campaign targets and extolling the virtues of operator-inspection procedures. No attempt was made to examine auditing procedures and techniques in detail, nor to track improved performance over time. It was considered more important to examine: (a) the internal climate for continuous improvement in quality, and (b) how executives perceived these improvements to enhance competitiveness. The overall findings on both counts were somewhat disappointing. It must be concluded that for most SBUs, quality is perceived narrowly as compliance to a product specification and largely within the domain of the production function. By the end of 1988, institutionalised concepts of total quality management still seemed a long way off. On the question of enhancing competitiveness, great strides had been made, but it is difficult to ignore the fact that the ultimate measure of quality should be derived externally from an assessment of customer satisfaction, yet few SBUs had the marketing capability to carry this out.

4.33 External Relationships

4.331 A model for machine tool manufacturers based on strategic alliances

There is mounting evidence across a range of engineering and manufacturing industries to suggest that sustainable competitive advantages at the heart of "world best-practice" require the formation of strategic alliances with sub-contractors, component suppliers and customers. Such alliances are claimed to enhance the probability of successful implementation of "just-in-time" philosophies, materials requirements planning systems and full or partial computer integrated manufacture; all of which rely heavily on well developed internal and external infrastructure for their smooth running.

Throughout the 1980's the focus of attention has been the Japanese model of quasi-integration typically found in the motor vehicle and electronics industries, involving multi-layers of sub-contractors and component suppliers. Powerful manufacturers often hold minority shares in their first tier suppliers and tend to prefer long term contracts under single sourcing arrangements. High standards of quality and reliability are demanded, yet relationships tend to remain in tact because of apparent willingness to devote considerable time and effort to joint problem-solving. Other features include pricing linked to productivity, mutual disclosure on costing and extensive information sharing at the early stage of product/process design.

Associated with the above model is a school of thought which advocates the partial or full withdrawal from manufacturing operations and concentrating on product engineering, procurement, marketing and assembly. This approach has already found some support in machine tools and is based on the notion that resources tied up in plant and equipment are the least flexible and inhibit strategic adaptation. Amada, for example, the leading Japanese producer of metal forming equipment, is a successful exponent; and among West German producers, Trumpf and Scharmannn are showing the way.

The extent of external interaction in the UK machine tool industry and the readiness of manufacturers to embrace various elements of the integrative model will now be examined.

4.332 Linkages with sub-contractors

The outward sub-contracting of manufacturing processes is a common occurrence in machine tools and other engineering industries. Simultaneously, some machine tool manufacturers were found to be involved in both outward and inward sub-contracting, depending on the set of skills and facilities at their disposal and levels of capacity utilisation. Thus "make or buy" decisions have important implications for capacity planning and the level of value added by the business. They also reflect the willingness of executives to allow the separation of product design from manufacturing process.

Multiple reasons were cited for wholly or selectively sub-contracting manufacturing operations. Most executives claimed the existence of policy guidelines (or precedents) encouraging the sub-contracting of processes deemed to be uneconomic or disruptive to internal operations. In practice, this was either interpreted tactically, depending on economic conditions; or strategically as a continuing bought-in service (ie as an effective extension of capacity).

Tactical use of sub-contracting was common during the cyclic upturn of 1975-79 when it relieved bottlenecks; whereas during the downturn of 1980 onwards, cost was to the fore when machine tool manufacturers and sub-contractors had spare capacity. One approach adopted by several machine tool manufacturers, which had the sound strategic aim of stabilising operations, involved sub-contracting component manufacture during the introduction and decline phases of model life cycles. Pulling in component manufacture during the growth/maturity phases, however, was resented by some sub-contractors and soured relationships. In contrast, other machine tool manufacturers were reluctant to delete ageing models from the range and often felt it expedient to retain component manufacture in-house. Production managers admitted that continuing to produce declining models was disruptive and pointed to similar problems in the production of spares and in refurbishing work. Hidden costs associated with these activities were tolerated even though they could have been partially eliminated by either sub-contracting or more efficient use of machining centres. For some SBUs, lucrative spares business, together with refurbishing work, provided their main source of orders and justification for maintaining the workforce over the deepest part of the recession.

Careful consideration of the overall production cycle was evident in SBUs which had retained in-house manufacture of "core" components, especially those laid down first, and had sub-contracted less critical items. No clear dichotomy of good/poor practice emerged between manufacturers of standard and customised machines, nor was there a discernable pattern across the various machine types. Judicious make or buy decisions appeared to be one aspect of the professional approach to production/manufacturing management adopted by a few outstanding individuals.

Strategic consideration of the make or buy decision was at its best in SBUs in which senior production executives and engineers were quality-conscious and had thought through the implications of building machines from the "floor up". The most obvious examples of sub-contracting to achieve desired quality were found in willingness to use specialists proficient in certain operations such as gear cutting, precision grinding, sheet metal fabrication, electrical sub-assemblies etc. The quality of sub-contracted items was summed up by one Quality Director as:

> '....a very variable picture. 80-90 per cent we are comfortable with, the other 10-20 per cent require attention and take up a lot of our time .... Some sub-contractors have good "quality" but poor "quality management"'.

Later, the executive quoted above gave a seminar presentation at a professional institution meeting. In response to questions, he recounted the difficulties in changing attitudes among existing suppliers and sub-contractors and the need for auditing new suppliers as a prequalification procedure. He had been willing to help them achieve British Standard 5750 (Quality Systems) but noted that access to their plants 'had not been Japanese style'. Several production managers reported similar experiences. Rather like the findings on value engineering and value analysis, there was an underlying aversion to the level of formality and dedication required to "pursue the last grain of rice" so widely documented on Japanese companies.

4.333 Linkages with component suppliers

Many of the points regarding sub-contracting apply to bought-in components. Both involve a set of decisions related to the scale of operations and tying up resources. Additionally, there was a desire to ensure security of supply and to protect competitive advantages embodied in certain components. In CNC machine tools, for example, the critical component is the control unit, which may constitute up to 40 per cent of the total cost of a machine depending on size and degree of sophistication.

Worldwide, there are large machine tool manufacturers who produce their own in-house CNC systems (eg Cincinnati Milacron, Giddings & Lewis, Okuma) while others have formed strategic alliances (eg Yamazaki with Mitsubishi). In the early 1980's, the majority of machine tool manufacturers bought-in proprietary systems freely available in the international supply market from such producers as Fanuc (claiming an estimated 60 per cent world share), General Electric, Allen-Bradley and Siemens. Others include Philips, NUM and Anilam, together with a number of smaller specialist producers (eg Cybelec and Hurco in press brakes). Regretably, no UK-owned controller manufacturer or machine tool manufacturer was able to offer a CNC system equivalent to the Fanuc 6 and GE 2000. Europe's hopes lay with Siemens, while Plessey, GEC and others withdrew from the business, having failed to develop a world class system. By 1987, GE and Fanuc had formed a joint venture and dominated the market. The first major innovation likely to be launched by GE Fanuc will be the Series 16, based on the highly acclaimed RISC (reduced instruction set computer) microprocessor technology. Competitive systems will find it difficult to match this new generation of controllers for speed and precision when machining complex workpieces.

Some UK-owned machine tool manufacturers felt bitterly disappointed that they have had to rely heavily on imported systems to keep abreast of developments. Indeed, almost all executives had a bad experience of control systems to recount, frequently citing reliability as a major problem with earlier hard-wired NC systems; and in recent years, late deliveries and apparent lack of interest on the part of suppliers in servicing low volume CNC machine tool manufacturers in the UK. It is believed that these perceived shortcomings are partly responsible for cautious approaches to single sourcing by manufacturers and also for preferences among users for certain controllers. While noting these recurring themes in the interviews and their inhibiting effect on the development of long term relationships between manufacturers and suppliers, once they had been aired, many valuable inputs from controller suppliers were revealed (eg interfacing, training, touch-probing and diagnostic routines) which were much appreciated by product engineers.

For machine tool manufacturers, there are penalties for non-participation in the design and manufacture of CNC systems. Firstly, dependency on standard controllers means that machines tend to be designed around them, sometimes having to incorporate redundant multi-axis capability beyond that required to perform the job in hand to facilitate future enhancement. This is particularly noticeable in special purpose machines. Secondly, controllers, being based on microelectronics, present valuable process opportunities for unit cost reduction with cumulative volume. Generally speaking, access to low-cost controllers is a prime requirement for entry and continuing presence in smaller price-sensitive CNC machines. Hence the success of Japanese manufacturers in segments such as small CNC lathes, machining centres and electro-discharge machines.

Purchasing of other components aroused only mild interest in the interviews with executives. Responses centred on price and delivery of items such as bearings, ball-screws, hydraulics, servodrives etc, giving prominence to the leverage gained from volume off-take. Discussion of technological inputs from component suppliers arose in the context of performance and quality. These criteria were foremost in the purchasing of specialised sub-assemblies (eg indexing units, boring heads) and certain foundry items. Few close associations had emerged, possibly because the suppliers themselves were often also machine tool manufacturers. Some executives seemed more concerned about potential leakages of know-how through collaboration than overall benefits. Joint applications development in tooling, instrumentation and software had made important contributions to the state-of-the-art but the competitive advantages accruing to machine tool manufacturers were temporary and lay mainly in early adoption. Most forms of collaboration were on a project by project basis rather than resulting in a strategic alliance.

4.334 Linkages with customers

The substantive issue emerging from examination of relationships at the manufacturer/customer interface was the dominating influence of a strategic group of customers in the motor industry. Traditionally, these customers have accounted for about one quarter of annual purchases by value and they represented the highest proportion (16 per cent) of the installed base of machine tools in the UK.

The importance of customers in motor vehicles and components was mentioned by executives in 13 SBUs in this study (ie 28 per cent of useable responses). Of these, 9 SBUs highlighted Ford as continually pushing for improvement. The intensity of machine tool manufacturer/customer relationships was found to vary according to the magnitude of the investment to the customer, the extent of customisation and the stage in the process from specification to commissioning.

Negotiating machine tool sales or putting contracts out to tender are common procedures within the motor vehicle industry, though much interaction may take place before a specification is finalised. These documents tend to be compiled by engineers and buyers in the customer company after a thorough survey of current practice or by requesting selected machine tool manufacturers to prepare the best solution to a particular component machining problem. Many executives interviewed regarded the resulting specification as close to the "state-of-the-art" because it represented a distillation of what all competitors in the field are able to offer. This revealed the international nature of specifications and preferences in the motor industry. Some executives claimed that they could detect the influence of certain competitors and centres of automotive engineering (eg Cologne, Detroit, Dagenham).

Motor industry engineers frequently visited machine tool manufacturers to monitor progress, especially at stages requiring the sanctioning of part-payments. One executive said that customer's engineers were ....'almost living on the premises' and wanted to involve themselves 'to an absurd level' during proving runs prior to commissioning. He recalled with a combination of embarrassment and frustration, an instance when a grinding machine had not received initial approval because the cycle time was 3 second out on specification. Another executive felt that customer's engineers and buyers were judging his SBU not only on machine performance to specification, but also on their 'standard of housekeeping'. This last point seems to have been overlooked by all but a few enlightened executives familiar with vendor rating schemes. Even if such schemes are not formalised, the psychological effect of poorly organised plants, ageing equipment and inadequate control procedures, is often sufficient to ensure early exclusion from certain contracts. The best awareness of the commercial implications of deteriorating facilities was found among staff in the sales function. Many sales engineers felt that it placed them at a competitive disadvantage against importers - on the premise that having no manufacturing facility to show customers is often better than having a poor one. The lesson to be learnt is that discerning customers are as much interested in the processes of machine tool manufacturers as their products.

From the foregoing comments it is clear that motor vehicle companies, either in direct contact with machine tool manufacturers or indirectly through their component suppliers, are responsible for user-initiated innovation. Two outstanding initiatives from General Motors, for example, are: the introduction of programmable logic controllers in the early 1970's and Manufacturing Automation Protocol (MAP) to achieve networking compatibility, announced in 1982. These reflect General Motors' desire to set de facto standards in the industry, backed up by their immense purchasing power.

While it is encouraging to note that machine tool manufacturers in the UK have been willing and able to respond to such customers in the past, it is likely that in future, much closer "collaboration" will be necessary to deal with higher levels of interdependence and to receive early warnings of impending technological change. One major national competitive disadvantage for UK machine tool manufacturers in this respect is the absence of significant captive user experience along the lines of Toyota and its machine tool subsidiary, Toyoda; Fiat and Comau; Renault and Acma-Cribier. This is disappointing because intra-group user experience was one of the factors underlying the early success of the UK machine tool industry.

Outside the concentrated grouping of customers in the motor vehicle industry, only aerospace companies such as British Aerospace, Rolls Royce and several other top engineering companies were perceived by executives in machine tool manufacturers as 'moving them forward technically'. The majority of customers were said to be widely scattered and these have borne the brunt of allegations of conservatism.

4.34 The Reality of "Catching-Up" Strategies

While most executives were found to accept the notion of an integrative model, it is clear from the foregoing analysis that progress has been slow and fragmented. The reasons for this laggardly approach were not readily apparent during the exploratory phase of research and it was coincidental that the working proposition was framed in a way which artificially separated internal and external linkages for the purpose of analysis. It was only later that this separation suggested a two-stage process of "catching-up" behaviour in which all SBUs tended to tackle deficiencies in their internal systems first and only a few moved on to encourage external linkages implied in the second part of the working proposition.

It was not, of course, surprising to find emphasis on internal systems. These are within the control of executives and it was relatively easy to identify real progress in such areas as modular construction, cost containment and quality. The main problem with these improvements, however, was: (a) the preoccupation with technical performance, and (b) that in terms of competitive advantage, such improvements were either ephemeral or merely provided a minimum requirement for continuing presence in various segments of the machine tool market. It is difficult to envisage SBUs closing the gap on tenacious international competitors without recourse to a more systematic approach.

The greatest scope for catching up and exploiting opportunities for sustainable competitive advantage is evident in the external exchange relationships and strategic alliances stated in the second part of the proposition. External linkages were found to be important because maintaining close relationships with customers is an effective barrier to entry against foreign imports and machine tool manufacturers are becoming increasingly dependent on suppliers of proprietary components. Yet few machine tool manufacturers in the UK enjoy the level of customer loyalty in their home market as found in other industries and "arms length" relationships with suppliers are preferred. Selection of suppliers, for example, continues to be based largely on price/quality criteria. As one chairman of an SBU manufacturing standard machines put it: 'We are not close enough to them (suppliers). Perhaps what we should be doing is guaranteeing them levels of business in return for other inputs'. Significantly, he made this comment during an interview immediately after returning from his first visit to Japan.

The same ideology pervaded Alfred Herbert in the 1950's and 60's. Even though they occupied a powerful position in the industry, they were plagued with quality and delivery problems among their suppliers and sub-contractors, and never achieved the benefits known to accrue to benchmark companies outside the industry such as Marks & Spencer in retailing and IBM in computer systems. Investments by Japanese companies in machine tool manufacturing operations in Europe are already showing that some of the distinctive features of the integrative model are transferable, as they strive to meet stipulated levels of local content and replicate their manufacturing systems.

The working proposition is, therefore, accepted, with the following observations:

(a) The problems of approaching world best-practice in machine tools are primarily managerial rather than technological.

(b) Greater appreciation is necessary of how technical success can contribute to commercial success. This requires senior executives to transcend the narrow functional or "product" perspective to gain a total picture of their business.

4.4 ORGANISATIONAL BARRIERS TO THE TRANSFER AND ASSIMILATION OF FOREIGN TECHNOLOGY

The fourth working proposition is:

> Current organisation structures in machine tool manufacturing SBUs present a barrier to the inward transfer and assimilation of foreign technology.

4.41 Organisational Design Issues

With few exceptions, organisation structures in UK-owned SBUs have evolved primarily to handle internally generated technology; and in US-owned SBUs, to accommodate a blend of their own technology and that from their parent company. Irrespective of ownership, however, the predominant structure identified in machine tool manufacturing SBUs was that of functional specialisation. Depending mainly on size, SBUs were headed up by a chief executive or managing director with a board of directors carrying responsibility for the key functions, or a divisional director supported by functional managers. Given this functional differentiation, three organisational design issues stand out as important in investigating the inward transfer and assimilation of foreign technology:

(a) the need for organisational integration in the light of rapidly changing requirements for information processing and coordination;

(b) the persistent problem of how to introduce new technology while managing ongoing operations (ie "innovation versus efficiency");

(c) the mechanism by which foreign technology enters the organisation, with particular reference to the key players in the transfer process.

Although the literature on strategy/structure, integration/differentiation, organic/mechanistic structures etc provided a useful background for research, important gaps were found in the theoretical and empirical underpinning of organisational design and the process of implementation:

(a) little guidance is available on managing the introduction of new technology, especially during a period of contraction;

(b) there has been an historical tendency for strategy formulation and implementation to be considered sequentially, with minimal regard for continuity and feedback;

(c) simplistic conceptualisations often ignore the role of middle managers and the pervasive influence of political behaviour in accounting for divergence between intended (ie planned) change and what is actually realised.

4.42 Organisational Integration : Prescriptions and Practice

Organisational integration carries the connotation of both a process and an outcome. Consideration of integration as a process is discernable in SBUs which have actively sought synergistic benefits from the cross-fertilisation of ideas and experiences through using formal integrative devices and encouraging informal interaction. Emphasis on integration as an outcome or condition is tied up with the notion of "internal consistency" and is characterised by an advanced stage of functional interdependence (ie the realisation of systems benefits, with the SBU recognised as the legitimate organisational unit representing collective interests).

Higher orders of integration may, of course, be desirable at the corporate/SBU level but these are not considered in the present analysis. Thus pertinent questions for senior executives in machine tool manufacturing SBUs are: (a) how much integration is desirable and possible, and over what time period, (b) is the self-interest so deeply rooted in social divisions and political power bases likely to result in rejection of greater interdependence, and (c) what is the probability of successfully promoting integration through the Head of SBU or via the intervention of an external agent in the field of organisation development?

Consideration of these questions is not helped by statements from opinion leaders and reference groups with vested interests in technical consultancy and the sale of related capital equipment. The following three perspectives extracted from the research are relevant to the confusing, and often acrimonious, debate:

(a) The most radical approaches are advocated by management consultants and computer systems suppliers. Prominent among consultants in the field of factory automation is Ingersoll Engineers, whose high profile polemical style has stimulated awareness of the need for a "total business" response to wealth creation and competitiveness. Unfortunately, their repeated criticism of UK manufacturing practices has also had negative side effects. Evidence from this study suggests that some of Ingersoll's more important messages may be losing impact on an increasingly saturated audience and they may have inadvertantly alienated themselves from large sections of industry, especially the machine tool manufacturers themselves. Part of the problem would seem to be of their own making, but this cannot be easily separated from two related issues: firstly, up to 1988 Ingersoll's US parent company was involved in machine tool manufacture; and secondly, the 1980's saw waves of enthusiasm and scepticism concerning the likely pay-offs from computerisation in office and factory automation.

Ingersoll, to their credit, have never been associated with "technological fix" solutions and can probably claim greater concern for human factors than computer systems suppliers, who frequently seem preoccupied with information flows and leave the onus for organisation design with their customers.

(b) The larger machine tool manufacturers, as both suppliers and potential users of advanced manufacturing systems, have found themselves occupying the middle ground. Their promotional effort has largely centred on 'step-by-step' or modular aproaches, in an attempt to play down some of the wilder claims for computer integrated manufacture. Machine tool manufacturers were found to recognise that the bulk of their medium/long term business will comprise stand-alone machines and small scale flexible manufacturing cells. Though they have a keen eye on computer integration and the implications for information flows, they tend to equate integration with machine system compatability (ie technical change) rather than organisation structure (ie socio-political change).

(c) Proponents of continuous or incremental change were found in large numbers in the majority of SBUs studied. Executives in these SBUs were well aware of external calls that functional structures are anachronistic but notions of a "grand plan" for re-organisation were viewed with suspicion and often perceived to be 'platitudes', 'a passing fad' or ....'to hide ulterior motives'.

There are inherent dangers in the generalisation that nothing less than radical interventions are necessary or that incrementalism is sufficient. Different SBUs operate in different segments of the machine tool market and each SBU is at a different stage of readiness to change. Executives in all but the most laggardly SBUs were aware of the need for organisational adjustments of some kind and the general direction these should take. Greater flexibility, responsiveness, adaptability and integration were repeatedly espoused as desirable attributes for the future. Nevertheless, when executives were asked about the magnitude of the strategic problems facing them and the time frame for action, 'short-term survival' was invariably stated as their main aim, with the corollary of minimum cost and disruption. Thus it was not surprising to find that: (a) organisation structures proved remarkably resilient during economic recession and throughout the 1980's, and (b) executives were satisfied with downscaling operations, while simultaneously attempting to modify individual group roles (ie settling for "first order" change). In short, executives possess only two of the three main ingredients of the so-called "change equation": dissatisfaction with the present and a vision of the future. Few could extricate themselves from the short-term pressures to articulate the third ingredient - a comprehensive and practical action plan.

4.43 The Complementary Nature of Differentiation and Integration and the Role of Middle Managers

Executives exhibited varying perceptions of the need for integration in their SBUs. One proposition to which I continually returned throughout this research was that: the need for integration recedes along the strategy continuum from leader to fast follower and late follower. The reasoning behind this proposition seemed obvious initially and is well grounded in the literature, but became progressively more complex as various interactions were explored. SBUs close to the frontier of technology tend to be product-driven and employ more specialists, leading to a higher degree of functional differentiation. Further, it is widely accepted that functional groups are differentiated by their general outlook, educational background, priorities and time scales of their members; and that the mutually reinforcing effect of specialisation and organisation structure makes such differentiation highly visible. In contrast, in follower SBUs, where product specifications are clearly defined and they can focus on the leader, the need for integration may be less pressing and functional differentiation less visible.

Integration, it was assumed, would be equally amenable to observation and that a qualitative picture could be built up of commitment to integration by probing the incidence and membership of new product committees and problem-centred task forces, the 'handing over' of work at functional interfaces, etc. Unfortunately, while it was possible to discern a receding pattern of differentiation along the continuum, identification of the extent of complementary integration was much more problematic. This approach proved fruitful in identifying localised technical benefits, but the nature of wider organisational benefits was often obscured by internal turbulence among the ranks of middle managers.

During the first round of interviews with senior executives, it appeared that certain highly differentiated leaders had encouraged the use of integrative devices no more rigorously than found in many less-differentiated followers. This anomaly preoccupied my thinking for a considerable time and it was not until informal discussions had been held with middle managers and lower level staff that tentative explanations began to emerge. Leaving aside the massive redundancies and their effect on morale, middle managers appeared to absorb the full brunt of rationalisation. Some emerged overloaded, having found their new roles enlarged and/or unclear; and in several SBUs, contraction had meant the removal of a complete layer of management. This precipitated high levels of insecurity among these managers, often exacerbated by the growing threat from computerisation to their traditional role as "information brokers" and integrators. Two observations relating to the information processing role of middle managers and their discretion for self-initiated action are relevant in the context of strategy implementation:

(a) Leaders and fast followers were installing office and factory-based information technology at a faster rate than other SBUs. These developments were gradually displacing routine administrative aspects of middle manager's work but there was little evidence that they had devoted more time to work of higher priority. Indeed, life had become more frenetic. Much of the congenial face to face contact accompanying routine tasks was replaced by contact under conditions of increasing conflict, as typified by production managers "firefighting" to accommodate fluctuations in throughput and higher levels of customisation.

(b) Some middle managers described how they had experimented with integrative devices and, to a lesser extent, liaison roles; but staff reductions during recession had taken up the "organisational slack" and allowed teamwork to fall into neglect. Problems which might have almost automatically resulted in the formation of ad hoc cross-functional teams in better times were frequently being tackled by one person on a part-time basis with minimal resources.

Different interpretations of the meaning of integration were noted with position in the hierarchy and functional location. Heads of SBU emphasised broad communication issues and many regurgitated slogans associated with computer integrated manufacture, whereas functional directors and middle managers were more concerned with narrower operational aspects of coordination and control, often preferring to talk about flexibility more than integration. Further generalisations across the main functions should be treated with caution. While there is evidence to suggest that product engineers saw themselves at the centre of integrative activities, and sales and production staff as making their separate inputs, positive responses to this line of questioning tended to be skewed towards larger SBUs among the leaders and fast followers, especially those involved in customisation. Passive or nil responses were common among late followers and smaller SBUs, where it was often impossible to pursue a sensible discussion on integration.

On two issues, however, there was unanimity: (a) middle managers are relied upon to implement change, and (b) project management is the most popular way of handling technological change. Middle managers in leader and fast follower SBUs were highly project-orientated and it was here that new product introductions and contracts for complex machines provided the focus for integration. Further along the continuum, among the late followers and laggards, discrete projects were numerous but less visible, because technology was applied in a tactical way to update ageing product ranges or support customisation.

The main conclusion from this part of the research is that: (a) much of what had been achieved in the way of integration hinged on initiatives taken by middle managers, and (b) their style of communication, participation and negotiation provided a major influence on "realised" strategy. Further, it was clear from discussions with middle managers that inward transfers of foreign technology, whether from parent companies or licensors, were treated in a similar way to internally generated technology. Most SBUs forced foreign technology into their existing structures and procedures by setting up a project, largely on the premise that the introduction of any new technology is disruptive and exhibits peaks of activity. The critical difference eluding many senior executives was that while discrete projects have well defined beginning and end points, the inward transfer and assimilation of foreign technology develops into an ongoing relationship requiring boundary-spanning roles. SBUs with earlier learning in technology transfer catered for these roles in the design of their formal structures, whereas newcomers to technology transfer tended to proceed on a trial and error basis.

4.44 A "Funnel" Model of Inward Technology Transfer

Widespred adoption of functional organisation structures in product-driven machine tool manufacturing SBUs has led me to propose the three-stage "funnel" model of inward technology transfer and assimilation shown in Figure 2. The model is based on the transfer process in 17 US-owned SBUs and 27 UK-owned SBUs. Its significance will be apparent in the discussion under the present working proposition regarding the suitability of functional organisation structures, and further unfold under the next two working propositions on the evaluation of technology packages and the relative merits of various modes of transfer.

The first stage is consistent with models of strategic problem formulation, whereby product engineering considerations were found to strongly influence the definition of technological gaps and how they might be closed. This is not to suggest that inputs from other functions are excluded at this stage. Participation is a matter of degree. From cumulative analysis over the previous three sections it is

Figure 3: A Funnel Model of the Inward Transfer and Assimilation of Technology in UK Subsidiaries and UK Licensee Companies

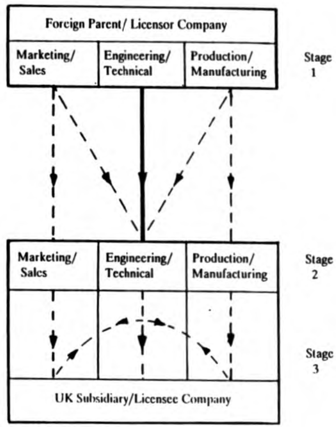
Comments:
Parent/Subsidiary
Relationships

Proposal made to parent company. UK managing director and engineering director lead discussions with inputs from marketing and production directors.

Project leader selected from any function but more likely to be from engineering function.

Ongoing contact between parent/subsidiary maintained within functions

Gatekeepers emerge in all three functions.



Comments:
Licensor/Licensee
Relationships

Negotiations typically by UK managing director with heavy involvement of engineering director.

Project leader invariably appointed from engineering function.

Inward flow of know-how primarily through engineering function. Cross-functional dissemination depends on management style of project leader and rigidity of organisation structure.

Gatekeepers emerge in engineering function.

Key

primary flow of know-how (solid line)

secondary flow of know-how (dashed line) clear that the inward transfer process is far from neutral and "funnelling" is likely to be accompanied by substantial "filtering" of incoming information, with the product engineering function providing the main entry point. Moreover, it is likely that combined funnelling/filtering will be a feature of all modes of inward transfer, and more intense among leaders and those exhibiting high levels of customisation.

The second stage involves increasing participation by other functions and its overlap with the first stage will be mainly dependent on when a formal project is set up and who is appointed to manage it. It is generally agreed that early formation of a project team, preferably a multifunctional team, encourages commitment and the interchange of information. Since project leaders or co-ordinators are normally seconded from the ranks of middle managers, however, the extent to which they represent continuity of existing values within SBUs, especially reinforcement of functional bias towards product engineering, may be a limiting factor on receptivity to incoming technology and on information dissemination. Other contingencies affecting assimilation at this stage include: (a) amenability of the technology to codification, (b) compatibility of supplier/recipient operating systems, and (c) capability of the recipient in adapting the technology at various receiving points within the SBU. The last point is related to the "critical mass" of skills and capital investment made available.

The third and final stage centres on the ongoing nature of supplier/recipient relationships after the bulk of the technology has been transferred. Some technologies are concise and the project may be wound up when the recipient achieves an agreed level of commercialisation. Other technologies require a long umbilical cord between supplier and recipient. Individual transfer projects are embedded in a wider network of formal and informal relationships in which ownership, control and the aspirations of senior executives play a prominent part. Formal ties between parent/subsidiary may be quite different from those between joint venture partners and independent licensors/licensees. Nevertheless, whether relationships turn out to be close or arms-length, transitory or open-ended, may ultimately depend on perceptions of the value of continuing relationships among senior executives and their willingness to nurture human contact.

Superimposed on all three stages of the proposed model are boundary-spanning roles. Some roles may be formally designated, while others may be called informal "gatekeeping" roles, emerging over time to make up for inadequacies in the formal system. Identifying and characterising gatekeeping roles was relatively easy in the case of long standing parent/subsidiary and licensor/licensee relationships compared with recent inward licensing arrangements. By probing well developed networks of relationships in which power bases had stabilised, it was possible to rapidly converge on incumbents of the gatekeeping role. In contrast, recent transactions were still in the early project stage and informal relationships tended to be in a state of flux. Thus it was necessary to split up the various transactions into subsets of 17 intra-company transfers between parent and subsidiary, 14 inward licences signed prior to 1980 and 17 inward licences signed after 1980. The following observations provide insights into the nature of gatekeeping behaviour in relation to position on the strategy continuum of leaders, fast followers and late followers:

(a) Heads of SBU were key individuals in facilitating the inward flow of technology through both formal and informal channels. Together with engineering directors, they played a prominent gatekeeping role in leader and fast-follower SBUs and handled proportionally more of the international communication than their counterparts among the late followers. This is consistent with earlier findings that Heads in leader SBUs were thoroughly immersed in product engineering issues and often travelled overseas accompanied by their technical directors.

(b) Middle/lower level gatekeepers emerged in leader and fast follower SBUs to handle technical complexity and they were mainly located in the product engineering function. These people were particularly important in the transfer of product applications know-how in technological segments such as special purpose machines, automated assembly equipment and robotics. Product engineering gatekeepers were observed in both US and UK-owned SBUs but in the former there were often other gatekeepers in the sales and production functions. The question of whether this is related to the enduring relationships said to be associated with parent/subsidiary ownership will be addressed in a later section.

(c) There was prima facie evidence to suggest that informal gatekeepers were not important in the transfer of mature and well-codified technology. Formal administrative channels appeared to be adequate in most cases and recipients able to assimilate the technology. Codification, however, has ramifications which are often overlooked. It not only includes drawings, manuals, computer software and other essential documentation, but also "embodied know-how" in the form of imported components, kits, etc. This on the one hand obviates the need for gatekeepers by easing assimilation, especially during start-up. On the other, there is a tendency for product-driven SBUs to opt for only those elements in the technology package which are easily codified (eg product technology) and to ignore or improvise on less codifiable elements (eg manufacturing process know-how).

(d) The highest incidence of middle/lower level gatekeepers was expected to be found in SBUs positioned along the middle portion of the leader/follower continuum. Unfortunately, many of these SBUs exhibited high levels of turbulence and lack of continuity, making it somewhat easier to locate gatekeepers than to assess the quality of their contribution. Certain gatekeepers interviewed early in the research, for example, had left the SBU by the time of my next visit. Some had departed of their own accord and others were declared redundant, yet senior executives were frequently unaware of the voids left behind in the informal communication system. This in itself is a valuable finding for organisational design but it precludes the kind of neat socio-metric mapping associated with some of the earlier research conducted in organisations during times of greater internal stability. Indeed, it is difficult to see how some of the contingency school of researchers have reached such positive conclusions about the direction of causality in strategy, structure and peformance, especially where their findings are based on static cross-sectional studies.

The validity of the "funnel" model of inward technology transfer hinges on the dominance of product engineering in functional organisation structures and the hitherto sequential nature of strategy formulation and implementation. I have since observed these two conditions in other product-driven engineering companies and the model may well have wider external validity. Nevertheless, the model emerged inductively from the research and further refinement and testing would require the collection and analysis of new data. An obvious starting point would be to conduct an in-depth analysis of the background and behaviour of informal gatekeepers, aimed at answering such questions as: (a) what are their personal characteristics, (b) what other boundary-spanning roles do they perform complementary to the inward transfer of foreign technology; (c) what improvements might result from suitable training and from job rotation, and (d) should these roles be designed into the formal system?

4.45 Robustness of the Funnel Model

The origins of the proposed funnel model may be traced through periods of relative stability during economic upturn and increasing turbulence during prolonged economic recession. Since recession triggerd a burst of activity in the inward transfer of technology, it is worth briefly analysing in general whether the extreme case of "crisis" suggests any modifications to the model. An interesting proposition, for example, might be that formal organisation structures are irrelevant in times of crisis and therefore do not present a barrier to inward technology transfer and assimilation. The following observations relate to this proposition:

(a) There is substantial evidence in the literature and from this research to support the view that an impending crisis allows turnaround decisions to be carried through by senior executives which would be considered unpalatable or totally rejected at other times.

(b) Executives were observed to be making decisions under personal stress, relying on judgement with less consultation, minimal supporting information and in a much-reduced time scale. In earlier sections, examples were given of unprecedented rationalisation, introducing new technology and signing licence agreements in situations where the external threat to survival was sufficient to allow these decisions to pass virtually unchallenged.

(c) Crisis is a temporary phenomenon. Resistance to change and self-interest rooted in traditional power bases was suspended during crisis and turnaround, but soon returned when the initial pain of recession had passed and stability was in sight. Again, although "second order" cultural change may have been desirable, only "first order" change was actually achieved.

The implications for the funnel modelof inward transfer and assimilation are clear. Rationalisation and staff redundancies tend to be one-off decisions, albeit far-reaching, whereas the introduction of new technology has to span the full period from initial decision to go-ahead, through to commercialisation and on an ongoing basis thereafter. It is here that the recurring problems of sequential separation of strategy formulation from implementation are to the fore, suggesting that: (a) stage 1 of the model, involving the initial decision and "transfer" of foreign technology, is most affected by crisis, and (b) stages 2 and 3 which encompass "assimilation", are least affected. With reference to the proposition, it would seem that the influence of organisation structure is relaxed, rather than irrelevant, under crisis conditions. In reacting to short-term threats, senior executives and middle managers seldom change the behaviour of a life-time.

The position of middle managers in the hierarchy and their functional location emerged in this research as a critical determinant of information processing efficiency at key points along the locus of innovation and technology transfer. Lack of attention to the burden placed on these managers impeded cross-functional initiatives as organisational slack was taken up, decisions were forced upwards and many managers retreated to the technical aspects of their functional specialisation. This regressive behaviour accentuated inherent biasses in the prevailing internal power structure over the period when SBUs were at their most vulnerable and some were struggling to assimilate foreign technology.

Further research would require consideration of the opposing forces for centralisation and delegation of decision-making affecting middle managers. Their importance was underestimated at the outset of this research and, consequently, some of the subtle hierarchical and cross-functional linkages may have been missed. Middle managers are an obvious target for management development, such as team-building, but it would be foolish to pretend that successful interventions are possible without first ensuring: (a) deeper understanding of human resource issues on the part of senior executives, (b) offering positive guidance on the direction and timescales for change, and (c) assurances that raised expectations can be met.

4.46 Penalties Associated with the Funnel Model

The fourth working proposition that current organisation structures provide a barrier to the inward transfer and assimilation of foreign technology is tentatively accepted. My reservations on full acceptance relate to lingering doubts surrounding the operationalisation of this proposition, mainly due to the problem of characterising behaviour during such a period of intense change. Some comfort is sought in the fact that such eminent researchers as Lawrence & Lorsch and Burns & Stalker encountered similar methodological difficulties under less turbulent conditions!

On the positive side, there is evidence to show that rigid adherence to functional structures and failure to promote adequate levels of integration in machine tool manufacturing SBUs has allowed discontinuities at functional interfaces and inhibited organisational learning. Given the imbalance in internal power relationships in favour of product engineering embodied in the funnel model, the dangers cannot be ignored:

(a) internal product engineering capability may become uncoupled from market need and/or out of line with external reality;

(b) packages of foreign technology may be sought and evaluated on their product-related elements and not on total benefits;

(c) product engineers may dominate formal and informal channels for technology transfer to such and extent that non-product elements are filtered out.

4.5 UNPACKAGING INWARD LICENCE AGREEMENTS

The fifth working proposition is:

> Major benefits are likely to accrue to licensees who "unpackage" agreements when evaluating the technology on offer from foreign licensors.

4.51 The Process of "Unpackaging"

Technology is normally licensed in the form of a "package" or "bundle" of tangible and intangible benefits and attributes. Conversely, "unpackaging", as recommended in most guidelines on inward technology transfer, is based on a systematic approach to evaluating the content of licence agreements. Emphasis is placed on separating out those elements which are associated with start-up and occur once (eg search costs, adaptation of documentation, initial training, purchases of capital equipment, down-payments) from other ongoing transfers (eg tied imports of intermediate components and materials, updated know-how) and deferred payments based on sales (eg royalties on intellectual property rights). Hence use of the word "accrue" in the framing of this working proposition in recognition of the dynamic and cumulative nature of technology transfer over time.

Consideration of the incremental contribution of each element in the package might be expected to give tactical advantages during negotiation and clarify the nature of long term commitment inherent in agreements. By raising these issues in turn with UK licensees and selected US licensors, it was possible to assess policy and attitudes towards unpackaging in such areas as core/peripheral technology, product/process technology, the form of payments, division of markets, etc. Particularly relevant in this respect was the need to explore: (a) whether licensees attempted to maximise or optimise perceived benefits while minimising costs, and (b) the existence of some rank order of preference for various elements of the package and sensitivity to trade-offs.

4.52 To What Extent Does Licensing Resemble "Systems Selling"?

For foreign machine tool licensors to adopt some of the customer-orientated principles of systems selling they would have to be willing to tailor their technology packages to meet the requirements of individual licensees.

Notions of licensors rigidly imposing their perception of what is required for successful transfer on prospective licensees, perhaps compelling them to pay for elements they do not need, are deeply rooted in the literature on technology transfer from Western countries to developing countries and, to a lesser extent, underlying the kind of negative feelings alluded to earlier. Abuses of power are not unknown in machine tools but only a small minority of UK licensees accused their foreign licensors of employing arrogant "we know best" approaches and showing little sensitivity to their needs. Evidence from this research suggests that such rigidity was often tolerated by licensees in the short term or in the case of "static" agreements largely comprising patent rights. Since 94 per cent of agreements were found to be "dynamic" (ie they involved ongoing flows of technology) then this would discourage improvements over the duration of the licence and any possible extensions.

Proponents of packaging, who were found to be mainly licensors, often cogently argued that the various elements of the package are so inextricably linked and the synergistic benefits so vital to a successful transfer that what they were offering must be viewed and evaluated collectively. Some prospective UK licensees were initially put off by the hard line on packaging pursued by US licensors during the pre-signing period. This was probed in discussions with US licensors. It was revealed that by far the most important factor underlying their reluctance to diverge from a standard tried and tested package was fear of losing control, especially if their trade mark was included in the package. Additionally, executives in licensor companies transferring technology deemed to be close to the state-of-the-art, were worried about secrecy and performance guarantees. It is important to note, however, that much of the seemingly uncompromising behaviour of US licensors during the early stages of negotiation was considerably relaxed once the transfer process got underway. Moreover, the composition of packages actually transferred depended largely on licensees' requests for assistance, with UK licensees often perceived as 'undemanding' by their licensors.

Further useful comparisons may be made with systems selling in that customers have been observed to evolve from being "unsophisticated generalists" to becoming "sophisticated specialists", tending to multisource inputs to the package, handle integration themselves and increasingly focus on price. Thus it would be reasonable to propose that: the more sophisticated the UK licensee, the more likely they would be to unpackage agreements for both analytical purposes and to seek only those elements for which they perceived themselves to be deficient. Sophistication in this sense being assumed a function of: (a) the licensee's general level of proficiency as a machine tool manufacturer, and (b) their experiential learning from earlier licensing transactions and other commercial arrangements of an international nature. Licensees might also be expected to focus on price (ie downpayments and royalties) as the technology approaches maturity and becomes more widely available.

4.53 A Brief Note on UK, US and Japanese Negotiating Styles

Although no attempt was made in this study to reconstruct the complex dynamics of licensing negotiations, two patterns of behaviour emerged from the interviews with senior executives which were corroborated through analysis of the composition of technology packages and further interviews. These concern the response of UK executives to the contrasting negotiating styles of US and Japanese licensors:

(a) US licensors have shown historically a high propensity for licensing "blanket" coverage of their product lines and territories outside their domestic market. This is believed to reflect preoccupation with their home market, marginal interest in exports and a desire for administrative simplicity. US licensors exhibited a marked aversion towards complex packages and dwelling on any point that might prolong negotiation. Such a loose approach to commercial exploitation was often at odds with their lawyer's emphasis on legal detail in contractual arrangements. In contrast, Japanese machine tool manufacturers, having learnt extensively from inward licensing in the 1950's and 60's, tend to licence selectively, product by product; showing caution in respect of granting territorial exclusivity and only moderate interest in contractual documentation.

(b) US licensors and UK licensees share many common aspects of culture and it would seem that the way they prepare themselves for, and conduct, negotiations is almost a mirror image (ie a well defined process involving 'concessions leading to compromise').

This negotiating behaviour contrasts sharply with experiences of negotiations described by executives in prospective UK licensee companies dealing with Japanese manufacturers. A small minority of UK executives had prepared themselves in almost normative fashion, while the majority 'played things by ear', often exhibiting social and commercial niaivity in the extreme. Executives in the first category had conducted extensive desk research and sought local assistance. Some were familiar with the cultural nuances of Japanese business methods from experiences gained through earlier agency agreements. The second category is typified by the example of a managing director on his third visit to Japan who described his surprise and discomfort in finding that his Japanese counterparts were unwilling to adopt a confrontational style of negotiation. As he put it: 'I met a lot of people and it took a long time to get things moving ....they kept saying "yes" to everything I said ....but I never quite knew where I stood until the day I left'. Another managing director visited Japan for the first time to sign a licence agreement. Much to the chagrin of his fellow directors, one of whom recounted the story, he spent only five days on the round trip, foregoing the opportunity to enhance his knowledge of Japanese industry and almost certainly offending his hosts.

The above observations are based on substantial experience of inward licensing from US companies over the postwar period and recent, though somewhat limited, experience of Japanese companies. US and Japanese international business strategies evolved under different competitive conditions and much of the evidence is anecdotal, but it is revealing and suggests that US licensors have been closer than Japanese licensors to the "systems selling" model. In practice, the leading Japanese machine tool manufacturers, like US manufacturers before them, have recognised that their technology is in demand and are exploiting it as part of a global strategy. The difference is that Japanese machine tool packages are tighter in every respect and they are as much about the control of markets as they are about technology.

4.54 Composition of Licence Agreements

4.541 The agreement as a point of reference for research

The licence document sets out the rights, duties and obligations agreed by both parties. As such it gives clues as to their intentions and provides a legal record of the outcome of negotiations.

When extracting the main elements of licence agreements for analysis and discussion with executives, it was found that the sequence of clauses followed widely accepted checklists, but the length of agreements and level of detail varied considerably, even for nominally the same machine tool technology. I had expected that product range and complexity of the technology would dictate the level of detail. This proved unfounded and licensor's attempts to circumscribe the technology and rights offered under licence were largely a function of their lawyer's approach to drafting agreements. The style of agreements ranged from tightly worded contracts aimed at covering every angle, to pragmatic working documents which relied on mutual goodwill and extra-contractual arrangements. Executives in licensor and licensee companies had a general preference for the latter, with the legal dimension perceived to impose 'a necessary constraint' on the relationship.

Three inter-related commercial and technological aspects of inward licensing were explored through the unpackaging process:

(a) Scope of agreements: including the definition of licensed machines, duration of agreements, exclusivity in manufacturing and sales territories.

(b) Industrial/intellectual property: specifically the strength of patents, use of trade marks, designs and copyrights, and know-how.

(c) Method of payment: including the relative importance of down payments and royalties, and the sensitivity to trade-offs implicit in (a) and (b).

Each of the above elements has its own set of legal constraints and implications for strategy and operations.

4.542 The scope of licence agreements

The following observations on the scope of agreements provide insights on how licensors staked out their technology and licensees accepted restraints on commercial exploitation:

(a) A precise definition of subject matter is generally regarded as important because it puts "a fence" around the technology package by stating what will be supplied at the time of signing and over the duration. The wording of these definitions was found to be remarkably loose in machine tool licences, especially in the width of product ranges, rights to improvements in technology and the identification of intellectual property.

(b) The duration of agreements did not emerge as a contentious issue. Fixed terms of 5 or 10 years were by far the most common, mainly depending on the expected length of time taken to transfer the initial part of the technology and to reach commercialisation. For some executives, expiry always seemed a long way off. Others typically assumed that almost automatic extension of the normal life of agreements on a year-to-year basis would take place. Few had assessed the exposure of their core technology after termination or the risks of premature termination.

(c) The extent of exclusivity of manufacturing and selling rights in various geographical territories was expected to be a key bargaining issue. In practice, the notion of evaluating and using territorial rights as a trade-off against other components of the package provoked little response among UK executives, other than defence of their negotiated outcome. Few had taken the stance that extending territorial rights offers the opportunity for future growth or a way of stemming the encroachment of foreign licensors who, outside the licensed territories, are in most respects competitors. The reasons for this lack of dynamism appear to lie partly in the disparate negotiating styles alluded to earlier, and partly in the inescapable fact that prospective UK licensees came to the negotiating table from a position of perceived weakness. Against ethnocentric US licensors, there would always be the real possibility of achieving manufacturing/ sales exclusivity in Western Europe, whereas globally-minded Japanese licensors had already gained a high degree of market penetration in Europe and could choose among prospective licensees. Most UK executives were satisfied with achieving their base-line position on territories of UK exclusivity in manufacturing and non-exclusivity in sales throughout the EEC.

4.543 Industrial/intellectual property

Executive's perceptions and the actual incidence of the four main elements of industrial/intellectual property in machine tool licence

Table 15. Average Weighting Attached to Licensed Patents, Trade Marks, Designs and Know-how by Heads of SBU for the Five Main Technological Segments

	Turning	Milling	Grinding	Metal Forming	Automation
Patents	1.3	2.1	3.0	1.8	3.1
Trade Marks	1.7	3.1	3.7	4.5	4.3
Designs	3.3	3.6	4.0	3.6	4.4
Know-how: product	3.0	3.9	4.3	3.0	4.5
process	1.0	1.6	2.0	1.8	1.3
commercial	1.7	1.6	1.5	3.0	2.2
Number of agreements analysed	3	7	3	11	7

Scale : 1(low) to 5(high)

Table 16. Incidence of Patents, Trade Marks, Designs and Know-how in Licence Agreements for the Five Main Technological Segments

	Turning	Milling	Grinding	Metal Forming	Automation	Total
Patents included at the time of signing agreement	2	5	2	7	5	21
Trade marks:						
Licensor's mark	2	2	2	7	2	15
Joint mark	1	4	1	3	3	12
Licensee's mark	0	1	0	1	2	4
Designs	3	6	3	11	6	29
Know-how	3	6	3	10	6	28
Number of agreements analysed	3	7	3	11	7	31

agreements are presented in Tables 15 and 16 respectively. The data was broken down by machine tool technology segment in order to capture the concentration of elements in particular licensing situations. The following observations give an overview of the key findings from an extensive analysis of the composition of technology packages:

(a) Patents were rated of low importance by Heads of SBU across the range of machine tool technologies, yet over two thirds of agreements included active patents at the time of signing. This is believed to reflect desire on the part of licensors, or more specifically their lawyers, to bring agreements under the umbrella of patent law, though the presence of patents frequently offered limited competitive advantage. This is not to suggest that sharing a key patent position has no techno-commercial value or offered no legal protection. The lawyer's maxim of "separating mere shadow from substance" should be applied when evaluating the contribution of intellectual property to technology packages. Both US and Japanese licensors had a higher propensity to patent their technology than their UK licensees. Indeed, this may well be symptomatic of the generally low level of understanding surrounding intellectual property and competition law among UK executives.

(b) Trade marks provided a useful focus for the assessment of marketing inputs to the evaluation of technology packages and revealed many of the constraints inherent in the "product-driven" paradigm in machine tool manufacturing SBUs. Executives in UK licensee companies felt uncomfortable when evaluating trademarks and this provided one of the few points of divergence from their generally similar approach to US licensors. Trade marks tend to be grossly undervalued by UK executives. Is this because understanding of their use as a positioning tool is not as well developed as in the US?

Several examples were revealed in this study of machines embodying relatively mature technology, yet enjoying strong awareness and reputation worldwide. This tended to be dismissed by product engineers and sales engineers in these licensee companies as of minor significance. They found the acquisition of such licences difficult to reconcile with cutbacks in their development budgets, leading to simmering discontent and partially thwarting attempts at repositioning.

On the positive side, exceptions were found among niche exploiters in special purpose and metal forming equipment, where executives rated trade marks highly and had sought qualitative answers to the question: "what benefits does sole or joint use of a licensor's trade mark bring?" From the tone of their replies, however, while they had consciously attempted to reposition themselves and followed this through in their marketing communications strategy, they relied heavily on internal assessments of "current" and "desired" position.

(c) Designs and Copyrights were rated highly across the range of machine tool technologies because they provide the main vehicle for communication. The quality of design drawings was found to have an important psychological impact on UK licensee staff, particularly middle managers, and this emerged as a key factor in gaining early acceptance of incoming technology.

(d) Industrial "know-how" has been widely interpreted as the cumulative stock of skills, expertise, knowledge, experience and information of a commercial and technical nature. Know-how covered by machine tool licence agreements is normally specific to particular projects, products and processes, and secret to the organisation in which it has been generated.

Strictly, know-how is not "intellectual property" and, therefore, does not enjoy the additional measure of legal protection and limited monopoly rights associated with patents, registered designs etc. Such a conceptual dichotomy has important implications for licensing: firstly, because the competitive advantage bound up in know-how depends on confidentiality and safeguards against leakages turn on what can be achieved as a contractual obligation of the licensee; and secondly, due to different treatment by the tax authorities and interpretation against the broader framework of competition law.

Know-how is the least concise element in the technology package and the most difficult to evaluate and transfer. This was no more apparent than during the pre-signing period when licensors sought a balance between whetting the prospective licensee's appetite and not divulging too much information in the event of negotiations falling through. The risks to the licensee are partially alleviated in the licensing situation because the technology has already been commercialised. Despite assurances from the licensor, the value of the know-how and the efficiency with which it will be transferred is unknown to the licensee. As one senior executive in a UK company fourteen months into a licence agreement commented: 'When you visited us a year ago we were in a state of euphoria. Our feet are now firmly on the ground and we have begun to find out just what it was that we licensed.' This "assymetry of information" often leads the prospective licensee to value the know-how less than the licensor. Yet such know-how is often hard won and the end result from many years unproductive exploration of blind alleys.

The findings on the relative weightings attached to product and process know-how leave much to be desired. To some extent this reflects the wider deficiencies of resource allocations to product/process development in machine tool manufacturing SBUs and willingness to improvise among manufacturing/production staff. More importantly, it suggests a bias towards product-related know-how when sourcing foreign technology.

The foregoing observations suggest that machine tool licences may be described as "low patent content - high know-how content" with growing importance attached to trade marks. Thus in order to evaluate the benefits stated in the working proposition, it is essential that the implications of high know-how content and trade marks are fully appreciated. Firstly, access to both of these elements of industrial property may continue indefinitely, providing there are mutual benefits for the foreign licensor and UK licensee. Secondly, unless it is continually updated, the competitive advantages embodied in licensed know-how may erode over time as it enters the public domain. Discussion on the kind of licensor/licensee relationships required to facilitate this updating, particularly in the case of tacit know-how, will be deferred to analysis under the sixth working proposition. Thirdly, evaluating and realising the market potential of a licensor's trade mark depends on substantial skills in marketing. In future, UK licensees must be more pro-active in tapping their licensor's commercial know-how.

4.55 Method of Payment

The payment provisions in machine tool licence agreements normally involve some combination of down payments and royalties. The breakdown of these transactions for the 31 agreements analysed is set out in Table 17.

Table 17. Incidence of Various Forms of Payment in Machine Tool Licence Agreements

Form of Payment	Number of Agreements	(%)
Downpayment on disclosure of written-up part of the technology:	10	32
Progress payments:	2	6
Minimum royalty payments:	7	23
Running royalty payments as percentage of invoiced sales price or a net sales price:	29	94
Running royalty payments as a fixed sum per machine:	2	6
N=31 agreements		

It can be seen from the above Table that running royalty payments provided the main focus of attention in the evaluation of technology packages. Three observations are relevant here:

(a) Most executives appeared to operate a "rule of thumb" for royalty rates with very little questioning of the base figure used for calculation, its relationship to cost structure and external comparisons of the going-rate for similar technologies.

(b) More experienced executives stood out from the rest due to their considered approach to inward licensing and their impressive commercial negotiation skills. They had sought trade-offs between royalties and downpayments, and related the former to "value added" instead of merely accepting the imposition of a percentage on invoiced sales price. It is not considered coincidence that 3 of these executives were the only ones to mention sales growth and market share targets, and their agreements were also among the lower quartile in terms of cash royalty payments.

(c) All executives had made rough estimates of payback period and translated royalty rates into what might be born as an expense in their margins. Less than one quarter of cases revealed a serious attempt to assess the yield or sensitivity of future streams of income over the duration of agreements.

The above observations show a greater preoccupation with costs (royalty payments) than benefits. When asked, for example, "what benefits does this licence bring to your company?", replies were predominantly product-related and centred on buying lead time. These findings correlate with earlier findings on short-term "order book" horizons, lack of market research and general inability to assess the long term impact of investments in technology and establishing market positon.

4.56 Elusive Linkages Between Costs and Benefits

The primary issue addressed by UK executives appeared to be whether or not to acquire a licence from a particular foreign manufacturer. From thereon, all other considerations were secondary. Executives often dismissed the additional cost and time associated with an extended search for licensees as not worthwhile, preferring instead to rely on 'commercial judgement' along the way to negotiating a satisfactory outcome. Although 'compromises' and 'mutual benefits' were said to reflect the dynamics of licensing negotiations, these had to be reconciled with later admissions by executives of either not knowing what to expect or rapidly modifying their expectations during the negotiation process. These are characteristics of 'satisficing' behaviour.

It is not pretended that unpackaging is easy to operationalise nor that it is feasible to source various components of the package separately from different suppliers as in the "make or buy" decision. Indeed, interactions are as critical as contributions from individual components. What is striking about the analysis under this fifth working proposition is that the learning process of unpackaging machine tool licence agreements is as important as the need to arrive at an acceptable form and magnitude of payment. It is, therefore, concluded that a more systematic evaluation would force executives to consider the strategic implications of their increasingly tactical approach. The fifth working proposition is therefore accepted.

4.6 TECHNOLOGY SUPPLIER/RECIPIENT RELATIONSHIPS

The sixth working proposition is:

> **The closer the machine tool technology is to the state-of-the-art, the greater the need for close relationships between technology supplier and recipient.**

4.61 Key Issues in the Transfer Process

This deceptively simple proposition is grounded in the literature, which portrays "state-of-the-art" technology as uncodified, undiffused and relying heavily on human interaction in the transfer process.

The empirical evidence presented so far in the previous sub-sections suggests that while ownership and control are key issues in the transfer of state-of-the-art technology, some of the generalised assumptions underlying normative choices of the mode of transfer may require qualification in the context of machine tools for the following three inter-related reasons:

(a) although the bond of ownership appears to best facilitate early access to new technology, my experience elsewhere suggests that this is seldom a sufficient condition to guarantee rapid adoption by the recipient;

(b) much of the theoretical and empirical work on international technology transfer in the past has been from the supplier's perspective to the relative neglect of recipient characteristics and supplier/recipient interaction;

(c) because state-of-the-art technology is tacit and ill-structured, it is open to selective interpretation and manipulation, depending on prevailing value systems and political behaviour among participants in the transfer process.

4.62 Macro-Level Observations on the Transfer of State-of-the-Art Technology

The most visible national preference for "human bridges" has emerged in the case of Japanese manufacturing companies, whether in the guise of the "ringi" system of achieving internal consensus or their approach to overseas investment and technology transfer. For evidence of their employment of ex-patriate managers and secondment of engineers during start-up, one need look no further than UK experience of inward investment in the electronics and automotive industries (eg Sony, Nissan, Komatsu). In the machine tool industry, the UK subsidiary of Yamazaki, the world leader in CNC lathes and machining centres, is the only example.

During commissioning of Yamazaki's greenfield plant at Worcester, temporary secondment of parent company staff peaked at 65 people, mainly engineers and technicians. When full production is reached, it is envisaged that about 10 of the 230 permanent employees will be ex-patriates, including the managing director. Similar involvement of Japanese nationals was known to have occurred when Yamazaki commissioned its first overseas plant in Kentucky, USA. It should be noted that I visited both plants during the course of this research. Others have also exhibited a high propensity for technology transfer through people, though their magnitude of investment and starting point varied considerably in each case. Okuma, for example, set up a greenfield plant in the USA; Makino chose to gradually acquire LeBlond in the USA and Heidenreich & Harbeck in West Germany; and Toyoda and Amada acquired Ernault and Promecam respectively, in France. All these Japanese manufacturers had established distribution networks in the host countries before investing in manufacturing plants. The spate of Japanese direct investment in the USA is expected to continue in response to the voluntary restraint on machine tool imports.

The experience of US machine tool manufacturers in setting up UK operations is somewhat different. Many executives in the 17 US-owned subsidiaries in this study spoke of substantial capital investment in plant and equipment, updating product ranges and training during start-up; yet the notion of appointing ex-patriate top management and the permanent secondment of staff was almost unknown. The reasons for this seemingly "hands-off" approach were cited by US executives as a combination of common language and culture and an historical belief in the capability of UK management. The last point implies the absence of a "managerial gap" and should be viewed with caution. There is contradictory evidence suggesting that plausible alternative explanations lie in the preoccupation of US executives with their home market and their faith in communications channels related to formal planning procedures. Over the course of this research only three US chief executives and one director were resident in UK subsidiaries. These exceptions were believed to be mainly in response to managing down operations during economic recession.

Discussions with Japanese executives revealed a deep concern about the effect of language and cultural dissimilarities on success of their overseas operations, together with a strong desire to expose employees to Western culture. This partially explains Japanese manufacturers' high propensity for interchange of people in the transfer of tacit knowledge, information and experience. There is also reason to believe that codification of new technology and its role in diffusion carries greater priority than in US and European machine tool manufacturers.

Sufficient anecdotal evidence emerged from interviews to suggest that a "standard design" may emerge earlier in Japanese manufacturers and that they have been able to compress time scales for new product innovation.

Japanese parent companies have sought rapid codification of technology through production engineering, often to the extent of replicating plant, equipment and systems in their overseas subsidiaries. Propositions along these lines would need to be tested in greater depth than is possible here. If these were accepted, it would mean that investing in computer-aided design and manufacturing systems, for example, presents opportunities to erode Japanese competitive advantages along the dimension of lead time. What is more difficult to match, however, is Japanese up-front commitment to production engineering and joint development with component suppliers which underpins opportunities to speed up the international transfer of technology.

4.63 "Access" to Technology is Not the Same as "Use" of Technology

From a sub-set of 17 intra-company transactions and 22 inward licensing transactions, the following comparison highlights the constraints imposed on access to technology and its commercialisation:

(a) Most UK subsidiaries were allowed relatively free access to their US parent companies and other subsidiaries. Some UK executives were members of corporate new product/process committees, giving them the opportunity to assess new technology as it unfolded. Such early access, however, was found to be a poor guide to whether UK subsidiaries would be permitted to build and/or sell particular models and product lines. US parent companies exercise tight control over product range, sourcing arrangements and sales territories. There is also a strong tradition among parent companies of testing prototypes and early production models in their domestic market for at least 6-12 months before giving the go-ahead to UK subsidiaries. The first few machines sold by UK subsidiaries were typically imported, followed by kit assembly and full manufacture. Decisions regarding progression are often linked to volume sales and there is no guarantee that full manufacture will ever be reached, nor that production will not be switched to another location at some future date.

(b) Licensees normally only gain access to their licensor's technology after it has been proven in the market place and after an agreement has been signed. Because of the assymetry of information between licensor and licensee, the latter is in a state of "buyer uncertainty" which hinders assessment of the technology on offer. There may also be other delays due to search procedures and protracted negotiations. The same sequence of imported machines and kits through to full manufacture is also evident in licensing. Licensors normally place territorial restrictions on sales; but unlike the case of subsidiaries, licensees retain greater control over the composition of their product range and its manufacture.

The trade-off implicit in the above comparison is clear. Foreign ownership may facilitate earlier and fuller access to state-of-the-art technology than is likely via licensing. The downside involves foreign control over manufacture and commercialisation. From the data in Table 18, UK subsidiaries of foreign parent companies also appear to commercialise new models and reach full manufacture quicker than licensees. This may be largely attributed to the in-built delays inherent in external transactions.

The crude data on transfer times indicates the scope available to US parent companies and their UK subsidiaries in reducing lead time should

Table 18. Timescales for the Inward Transfer of Technology

Stage in the Transfer Process	Intra-Company Transfer Times (months)	Licensor/Licensee Transfer Times (months)
Mean time from the decison to go-ahead in the new product area to:		
(a) commissioning of the first imported machine from the parent company or licensor	16.1 (SD=7.1)	18.3 (SD=8.3)
(b) reaching 70 per cent local manufacture by value	23.6 (SD=9.8)	31.5 (SD=12.2)
	N=12	N=14

they decide to opt for simultaneous model launches or shorten testing times in their home market. The wide dispersion about the mean in both modes of transfer is due to the mix of standard and customised machines in the subset of transactions studied.

Wholly-owned operations present opportunities for more enduring and far-reaching relationships than found in most licensing arrangements. This is not to suggest that all parent/subsidiary relationships are completely open and conflict-free, nor that all licensor/licensee relationships are adversarial and conducted at arms length. Indeed, it is possible to point to examples of parent/subsidiary relationships at such a low ebb as to be almost unworkable and to examples of licensing where the social bond transcends the formal techno-commercial arrangements laid down in the agreement. But even in the most stable licensing relationships, the underlying competitive situation is prone to surface; perhaps triggered by one party feeling the need to reallocate resources away from the licensed technology or pressure to renegotiate the agreement, especially during a period of prolonged economic recession and technological change.

On closer examination of the subset of intra-company transactions and inward licensing transactions it was found that after the first lump of technology had been transferred at start-up, the onus for initiating the continuing flow of technology tended to switch from supplier to recipient. This means that if recipients fail to "pull through" the technology, then the dynamic state-of-the-art element will be lost. This point is crucial because executives in several US licensor companies perceived their UK licensees as 'undemanding' and not always making full use of the technology available. Similar views on the apparent laggardliness of UK subsidiaries also emerged in interviews with executives in three US parent companies. On following through these views in UK subsidiaries and licensees, what was perceived by US executives as laggardliness or dis-interest was in reality the potent combination of the tendency of UK staff to undervalue external sources of technology and the pervasive belief that they could tackle any problem that came along. This places a high premium on top management's ability to recognise the need for interaction and their willingness to invest in it.

The managerial style of top executives emerged as a major determinant of the nature and extent of interaction. State-of-the-art technology flowed most freely in cases where UK executives encouraged middle managers and engineers to visit their parent company or licensor, thereby allowing informal communications channels to flourish. In the case of wholly-owned subsidiaries the frequency of overseas visits by middle level staff was estimated to be qualitatively higher, in several cases an order of magnitude higher, than found in licensing arrangements. Moreover, while staff visting parent companies tended to be drawn from the three main functions of product engineering, sales and production; staff visiting licensors were predominantly product engineers. This bias is a further manifestation of the product-driven approach to technology transfer. On the negative side, some top executives in these subsidiaries and licensees seriously impeded the flow of technology. This was not a deliberate attempt to sabotage relationships, but by insisting that all communications should be channelled through themselves. Such behaviour, reinforced by functional organisation structures, obscured access to the potential competitive advantages from state-of-the-art technology and reduced the efficiency of assimilation.

4.64 The Special Case of Applications Know-How

Some machine tool technologies are more know-how intensive than others. Automated assembly machines, robots, transfer and special purpose equipment were found to be particularly dependent on applications know-how. Progress towards machine systems has given new meaning to the expression "the products of the machine tool industry are the processes of user industries".

State-of-the-art applications know-how is generated at the machine tool manufacturer/user interface. This makes it customer-specific and one of the most sensitive forms of know-how. Both parties stand to benefit from developing closer relationships, particularly in dealing with complexity and reducing time scales; yet Western companies have not found it easy to reconcile the competitive advantages with their worries about becoming locked-in to each other.

Machine tool manufacturers have access to many users and their cumulative stock of applications know-how is much sought after. Herein lies the sensitivity: on the one hand, transferring this know-how to a third party such as a subsidiary, joint venture partner or licensee raises questions of leakage and breaches of confidentiality. On the other, if both machine tool manufacturer and user are multinationals, then distinct commercial and technological benefits may accrue to participants in an extended network of relationships. Many instances were identified in this research of UK subsidiaries and licensees gaining orders for machines on the strength of their ability to meet specifications of US origin combined with assurances of local supply and after sales service.

State-of-the-art applications know-how was found to be a complex amalgam of ideas about the right and wrong ways to do things, often involving hard won experience through a process of trial and error. Executives views about how this know-how should be transferred varied according to the complexity of the package. Know-how associated with say a robot gripper or a way of using jigs and fixtures, was often considered as embodied in the skill of applications engineers and easily transferable via "show-how" on a "learning by doing" basis. In contrast, the configuration of machining cells or complete flexible manufacturing systems was regarded as team-specific, requiring enduring relationships if the know-how is to be transferred project by project or as it unfolds. These extreme examples provide prima facie evidence for wholly-owned operations as the appropriate mode of transfer, with numerous opportunities for considering intermediate levels of direct investment such as joint ventures.

4.65 Why is there a Low Incidence of Joint Ventures in the UK Machine Tool Industry?

There is strong evidence to show that licence agreements have been preferred to joint ventures by US and UK machine tool manufacturers over the post war period. Does this indicate that licensing is perceived as a more versatile mode of transfer than advocated in the literature? Alternatively, does it suggest that only mature technology is traded in the external market or is there some underlying objection to joint ventures?

Only two current joint ventures were identified and investigated in this study. Both involved Japanese partners in 50:50 equity holdings and the motivation for forming the venture was said to have come from the Japanese partner who contributed the technology. Operating responsibility lay with the UK partner but there was little to distinguish behaviour of these joint ventures from that of conventional licensing arrangements. At the time of writing (ie about 5 years after start-up) neither had progressed much beyond low volume kit assembly.

One of the main reasons for the absence of joint ventures lies in the historical dominance of the US as the source of machine tool technology and the uncertainties surrounding anti-trust legislation. The US Department of Justice interprets the competitive effects of joint ventures under a "rule of reason" and the courts have increasingly recognised the benefits of increased efficiency through integration. Nevertheless, US executives have avoided forms of "collaboration" involving shared ownership and feel much happier with arms length licensing. There is also fragmented evidence to suggest that some US manufacturers treated their licensing transactions as "windfall" income and were not prepared to enter into the kind of managerial commitment implied in joint ventures.

Interviews with UK executives revealed that the low incidence of joint ventures may be partly attributed to fears of domination by a stronger partner and loss of independence, particularly in smaller companies; but mainly due to the startling ignorance of collaboration in general. From a subset of 27 UK-owned SBUs, 15 per cent of respondents were predisposed towards joint ventures, 29 per cent against and 56 per cent offered no opinion. 62 per cent of respondents were not aware of at least one of the two UK/Japanese joint ventures mentioned previously. Despite increasing exposure of collaboration in the press, 71 per cent were unable to point to joint ventures outside the machine tool industry as a possible vehicle for discussion. An estimated one third of the inward licence agreements covered in this study had not given serious consideration to joint ventures as an alternative mode of transfer. These findings present further evidence of the narrow domain scanned by executives.

4.66 A Note on the Codification and Assmimilation of Machine Tool Technology

Returning to the theme of technological gaps, acquiring state-of-the-art technology to catch up involves recipients moving from an existing position of dealing with predominantly mature (codified/diffused) technology to a new position which requires the capacity to handle new (uncodified/undiffused) technology. A similar problem arises when machine tool manufacturers acquire technology to diversify. Though they may be leaders or fast followers and competent in machine tool technology generally, the incoming technology is still new to them and highly specific to the supplier.

Extending this line of reasoning further is important because the most difficult transition is normally encountered in manufacturers of standard machines in medium/high volume. This is where the greatest mismatch is found between technology supplier and recipient, and where externally sourced technology is disruptive to existing operations which use dedicated plant and equipment. Conversely, manufacturers of highly customised, low volume machines are often sufficiently adaptive as to assimilate incoming technology with minimal dislocation. These operations currently represent end points on the spectrum of batch production processes, with most manufacturers falling in the middle ground and drifting towards higher levels of customisation. The introduction of flexible manufacturing systems will move batch production closer to that of continuous production. Whether this increase in sophistication and capital intensity will ease assimilation of foreign technology, may ultimately depend on compatibility between the equipment and internal systems of supplier and recipient.

4.67 Progress in the Technology of Technology Transfer

Faced with shortening model life cycles and lengthening development times, three trends present major opportunities to accelerate dissemination of firm-specific technology:

(a) Computer-aided design/manufacturing (CAD/CAM) databases offer considerable potential for codifying and sharing technology, providing both supplier and recipient possess the requisite hardware and software and there is compatability of systems. During my visit to the USA, the status of CAD installations was investigated. It was noted that 12 of the 16 US parent companies studied had installed CAD systems from reputable suppliers (eg IBM, Computervision, Integraph), but only 3 of their UK subsidiaries had compatible systems. A further 2 UK subsidiaries had received approval for capital expenditure. At that time, 19 of the US licensors and 4 UK licensees were known to have installed CAD systems but none were compatible. This shows the US lead in the application of CAD in machine tools and raises questions about the kind of commitment required if the benefits are to be realised. Compatibility in CAD/CAM is a pre-requisite of joint design and development programmes.

(b) Telecommunications technology is likely to enhance the transfer of know-how by lessening the need for expensive and time consuming meetings between supplier and recipient. Facsimile machines have added a welcome new dimension to written communication in the 1980's and teleconferencing is promising to be the most important development in the 1990's. Large multinationals in computer systems and office automation are among the early adopters of teleconferencing. Sharing experience in the design and operation of complex machining cells and large flexible manufacturing systems seem obvious applications. Adoption by machine tool manufacturers will largely depend on reducing the cost of transmission.

(c) Expert systems and diagnostics equipment provide further examples of how computerisation might enhance the transfer of applications know-how.

The above developments further emphasise the widening gap between: (a) manufacturers of stand-alone machines and those active in automated systems, and (b) between global and domestic players in machine tools. Introducing new information/communications technology into the transfer process itself opens up avenues of speculation about shifting internal power bases and the likelihood of triggering new forms of political behaviour.

4.68 Unqualified Support for the Adage "Technology is Best Transferred Through People"

Access to state-of-the-art technology and its rapid adoption are pre-requisites to achieving and sustaining international "best practice" in mainstream machine tool segments and in narrow niches. Given the tacit, ill-structured and proprietary nature of state-of-the-art technology, acceptance of the proposition turns on empirical evidence of recognition of the need to develop close relationships between supplier and recipient. The normative stance is that such relationships are best facilitated by wholly owned operations, with joint ventures and licensing as second and third preferred modes of transfer respectively. No evidence was uncovered to suggest that this order of preference should be rejected.

The extent to which ownership, hierarchy and control impinge on supplier/recipient relationships and what is actually transferred in the technology package, is a matter of concern. Consideration of inward transfer of the "dynamic" elements of state-of-the-art technology, especially applications know-how, from US machine tool manufacturers supports the view that the "potential" for close and enduring relationships resides in ownership.

One of the main factors in determining whether the benefits are realised in practice is executive behaviour. Cooperative styles of management and encouragement of boundary-spanning roles at key points along the locus of inward technology transfer were found to greatly enhance the internal dissemination of technology. Foreign direct investment by

Japanese machine tool manufacturers also lends support to this view, though they are at a different stage of international development and comparative evidence is incomplete. Experience so far, suggests that due to cultural dissimiliarities, UK employees may need to substantially modify their approach in order to accommodate the differing style of assimilation in Japanese companies. It is one thing to note Japanese willingness to invest in plant and equipment, and their penchant for secondment of people. It is quite another to characterise the social processes among ex-patriates and permanent UK staff so vital in the transfer of a comprehensive package of managerial and technological know-how.

Joint ventures have emerged as a compromise solution in machine tools. This is partly the desire to retain some of the commitment and close relationships believed to underpin wholly owned operations, and partly to attract Japanese technology. The low incidence of joint ventures in the UK machine tool industry was disappointing from the empirical perspective. It was hoped at the outset of this study to match pairs of joint ventures and inward licences to compare transfer mechanisms. Establishing the underlying reasons for reluctance to enter into joint ventures is in itself a valuable finding for intervention, especially in the light of recent UK Government initiatives to promote intra-EEC collaboration. Once again, however, this points to the recurring danger that the Government may be urging manufacturers to collaborate, without understanding the sensitive issues underlying its historical absence.

There seems little doubt that the proposition should be accepted. Close relationships between supplier and recipient were found to be at the heart of successful transfer of state-of-the-art technology. This was crucial in the past when technology transfer focussed on stand-alone machines and will be increasingly important in the future with increasing scale and/or complexity of manufacturing systems.

4.7 THE LOCATION OF RESEARCH, DESIGN AND DEVELOPMENT FACILITIES

The seventh working proposition is:

> Foreign parent companies of UK subsidiaries operate an international technological division of labour; centralising their research, design and development activities in their home country, to the detriment of the UK industry.

4.71 The International Technological Division of Labour

Resurgence of interest in the location of technical facilities is mainly due to the wave of Japanese direct investment (albeit from a low base) in Europe and North America, and the continuing debate on the nature of globalisation. While it is inappropriate here to present a detailed account of the many facets of globalisation, analysis will focus on two inter-related issues:

(a) the response of foreign machine tool multinationals to the shifting pattern of world competition, with particular reference to the technological divison of labour;

(b) the repercussions felt by their UK subsidiaries.

Selection of the above issues represents a deliberate attempt to widen analysis on the foreign sourcing of machine tool technology by examining empirical evidence against developments in such thorny areas as parent company ethnocentrism, the divisibility of R&D, Government intervention and perceptions of "good citizenship".

4.72 US Machine Tool Multinationals : From Ethnocentrism to Polycentrism?

Prior to 1979/80 there was ample evidence to support the first part of the working proposition. Many of the larger US multinationals operated corporate R&D facilities and technology flowed primarily from parent to subsidiary. Numerous examples of parent/subsidiary and sibling rivalry were uncovered but the nature of the relationship was clear: the role of the UK subsidiary was to concentrate on the "Europeanisation" and minor "customisation" of US designs. Modifications regarded as outside the scope of customisation had to be referred back to the parent company for approval.

The first challenge to this historical dominance came mainly with diverging requirements of the European and US markets, repeatedly stated by executives in UK subsidiaries as the need for "flexible" and "dedicated" machines respectively. These executives charged their counterparts in US parent companies with slowness in recognising world trends and felt that US customers would eventually demand greater flexibility. Many examples were cited in this research of conflict surrounding the choice of CNC systems and myopic response to particular machine features and configurations. That UK executives should accuse their parent companies in this way is an interesting paradox in the light of what has been stated already about UK SBUs in which parochialism and the "not-invented-here" syndrome are rife.
These shortcomings were exposed during the 1980's and there were knock-on effects in UK subsidiaries.

From interviews with US executives and subsequent tracking of the strategic behaviour of parent companies, there is mixed evidence to suggest that attitudes towards dispersion of research, design and development were radically changed during and after recession. One vice-president regarded dispersion as 'unthinkable' and another as 'not on the agenda'. Several others clearly favoured centralisation of research in the US but were unsure about the future dispersion of design and development. Computer aided design was recognised as creating an opportunity for partial dispersion which avoided duplication and retained parent company control. The strategic impact of CAD, however, as a tool for international technology transfer, possibly two-way, had received little serious thought; mainly because short-term "survival" was the main priority and foreign operations seldom considered a significant part of total operations.

The UK was perceived by most US executives as a sluggish economy with weak customer industries and so did not warrant setting up an R&D facility. When asked to expand their view of the UK in the wider context of Europe and the benefits of perhaps selectively locating R&D facilities close to centres of excellence (eg Universities possessing world-wide reputations for machine tool technology such as Aachen, and lead users such as Ford), the responses were shallow and ill-informed. This line of questioning carried the implicit propositon that R&D is becoming more "footloose" than in the past and was also used as a vehicle for opening discussion on the desired mix of research, design and development. West Germany was often cited as strong in both machine tools and the motor industry, but US executives appeared to know very little about individual manufacturers and recent developments.

Though corporate R&D facilities were often the last part of the parent organisation to be rationalised, most were eventually reduced in size and refocussed or dismantled. From the point of view of UK subsidiaries, the outcome was not all bad and some were the beneficiaries of their parent company's review of international logistics. As the following important exceptions show, after years as recipients of technology, four UK subsidiaries were assigned major responsibilities and given the freedom to generate their own technology:

(a) Cincinnati Milacron, once the largest machine tool producer in the world, implemented three major reorganisations in the 1980's. After an expensive, aborted attempt to gradually shift its R&D resources towards new business areas such as silicon wafer technology; it continued to support machine tools, robots, plastics processing, controls and software. It was the last reorganisation involving the setting up of "focussed factories" that proved to be the most far-reaching. The UK subsidiary emerged as the world source for machining centres, and for the first time, it was given design and manufacturing responsibility for two new vertical models launched in 1989. In contrast, the main loser in Europe was Cincinnati's sister plant in Holland with the decision to centre the grinding machine product line at a site in the US.

(b) Ex-Cell-O was another US manufacturer to embark on an extensive rationalisation programme involving devolution of responsibility for machine tool technologies to its two European subsidiaries in the UK and West Germany. The UK subsidiary had expertise in transfer equipment and high precision grinding machines and wished to reduce its dependence on the automotive industry. Aerospace was identified as a target segment and project leadership was awarded for a new range of CNC form grinding machines for turbine guide vanes and segments. Unfortunately, although this venture was highly successful technically, the European operations were subject to a management buy out in 1987 led by the dominant West German company who closed the loss-making UK manufacturing operations a year later with the loss of 250 jobs.

(c) Litton Industrial Automation Systems provides an outstanding example of what can be achieved when policy on the external sourcing of technology is relaxed. In 1982, Litton's UK subsidiary, Landis Lund, received the go-ahead to design and develop a range of sophisticated CNC cam lobe grinding machines in collaboration with the Cranfield Unit for Precision Engineering. Orders for this machine passed the 100 mark in mid-1987 and the company received the Queens Award for Innovation.

(d) And finally, the UK subsidiary of Bridgeport Machines designed and developed its own range of vertifical machining centres alongside its inward licence agreement with Yasuda of Japan for horizontal machining centres.

Four examples do not constitute an industry-wide transformation but they do illustrate diverse recovery strategies towards similar ends. Cincinnati Milacron and Bridgeport compete against low cost Japanese manufacturers such as Yamazaki, Okuma and Makino in the crowded mainstream machining centre segment. They meet these formidable competitors worldwide and are two of the few Western manufactureres capable of mounting a challenge to Japanese superiority. Ex-Cell-O and Landis Lund operate in different narrow niches in the grinding field, where product innovation and early capture of key customers are determinants of success. Ex-Cell-O is holding its own against

Hauni-Blohm, and Landis Lund against Schaudt and Fortuna. Taken together, these four represented 55-60 per cent of the sales turnover by value attributed to US subsidiaries in the UK in the mid-80's. Bridgeport and Landis Lund were two of only a handful of companies in the UK to report a stream of profits throughout the 1980's.

4.73 The Feasibility of Seeking Safeguards

There is a school of thought which generally favours inward foreign direct investment but preferably accompanied by assurances of a comprehensive transfer of technology and monitoring procedures. Responsibility for such procedures normally falls on government agencies and may be observed in its extreme form in the Eastern Bloc and developing countries. The closest the UK has ever been to vetting and monitoring foreign direct investment was in the late 1960's when the Ministry of Technology requested disclosure of information on a range of sensitive policy issues such as composition of the board of directors, expansion plans and intra-company trading. This approach brought resentment from the multinationals and was eventually relaxed because it was impossible to police. It would seem that the only way to provide effective monitoring is from the inside (ie via a share holding of some kind which permits access to key decisions). This would, of course, find little support in the UK political climate of the 1980's and into the 90's.

Despite Government reluctance to intervene in corporate affairs, the UK is vying for inward foreign direct investment in the EEC along with other member nations and various financial incentives are being offered. These incentives present an opportunity to seek safeguards in the "national interest". In practice, their scope has tended to be limited to specified levels of local content and proportions of production for export. Assurances in the case of Yamazaki, for example, were 60 per cent local content and 80 per cent exports. The DTI was unable to persuade them to manufacture CNC systems in the UK (in collaboration with Mitsubishi) and to set up an R&D facility. It is reasonable to speculate that further constraints may have caused Yamazaki to site their new plant elsewhere. Similar fears of switching resources were apparent in decisions concerning incremental investment by US-owned machine tool manufacturers in the UK who possess other plants in the EEC, though the threats have never been as blatant as in motor vehicles, pharmaceuticals and electronics.

Further scope for encouraging local R&D and the full transfer of technological know-how lies in providing "conditional" support for product/process innovation and plant modernisation. Two examples illustrate these points and the difficulties that arise:

(a) In 1979, Unimation, the US pioneer in robotics technology, received joint funding from the Department of Industry and the National Research & Development Corporation for the design, development and production of the Puma electric robot at Telford. The award was conditional on achieving 75 per cent local content within 3 years and they actually reached 90 per cent in a few months. Unimation went on to establish a development unit at the University of Warwick Science Park and announced a £10 million expansion programme, which included the formation of a new systems engineering division.

In 1984, the US parent company was acquired by Westinghouse who, in an effort to rationalise operations and achieve profitability, transformed it from a highly entrepreneurial organisation to a division subsumed in headquarters bureaucracy. Telford was retained as Unimation's European headquarters. Later, when the UK market for robots failed to live up to expectations, a decision was taken to retain production in the UK and move European sales and support operations to Frankfurt where the market was relatively buoyant.

(b) The DTI's list of authorised consultants in advanced manufacturing systems provided an opportunity to encourage the accumulation of systems expertise in the UK. Several UK subsidiaries of foreign machine tool manufacturers received approval under the scheme on the strength of their parent company experience. Yamazaki and White Consolidated Industries, for example, were approved under an arrangement whereby UK staff handled the initial proposal and staff from their parent companies in Nagoya and Cincinnati/Belvidere respectively would be called upon to prepare a full project study. Four years after receiving approval, Yamazaki's president gave further assurances that technology transfer would be 'aggressively promoted' and the UK managing director announced that a 'systems engineering division' would be set up at Worcester. In contrast, within two years of approval, White Consolidated was the subject of a buy-out by its UK managers, reverting to its former name of BSA Tools and severing the formal links on which approval was based.

The significance to machine tool manufacturers of gaining approval as consultants lay in specifying, albeit indirectly, their equipment in feasibility studies on which the client user would then be awarded a DTI grant. The disappointing feature of the scheme was not that approval of foreign owned subsidiaries as consultants was wrong in principle nor that their parent companies lacked the credentials. With lagging experience of flexible manufacturing systems and robotics installations in the UK, an external stimulus was necessary and the scheme provided a vital contribution to creating awareness and practical assistance. Unfortunately, the DTI virtually absolved itself of responsibility and approval required little more than answering a questionnaire. Imposing criteria regarding the number and quality of "permanent" UK staff would have simultaneously raised credibility of the scheme and tested the commitment of foreign parent companies in transferring systems know-how.

From this short analysis and earlier discussion on the technological division of labour, two observations may be made:

(a) agreements with foreign-owned machine tool manufacturers at the time of the investment may change radically with ownership and market conditions, especially in the case of embryonic technologies;

(b) safeguards are difficult to negotiate from a position of relative competitive weakness and require a level of sustained intervention beyond that which the present UK Government is prepared to support.

4.74 Decentralisation and the Divisibility of Research, Design and Development

The pattern of reorganisation among machine tool multinationals throughout the 1980's suggests that the first part of the proposition no longer holds as a generalisation. It is, however, difficult to envisage decentralisation of R&D to the UK by foreign multinationals on a grand scale over the next 5-10 years. Exploitation of firm-specific advantages related to superior R&D remain their raison d'etre, even if these have been eroded in recent years, and managerial attitudes still favour retention of R&D in the home country.

Assumptions about economies of scale and locational advantages were found to be at the heart of the centralisation issue. R&D is labour-intensive and there are often sound communications reasons for retaining team-specific skills on one site and then transferring their output to various subsidiaries when it is available in more codified form. Many parent companies were in danger of throwing the baby out with the bathwater when they dismantled their central R&D facilities. This is particularly noticeable in the case of new product development, which is multidisciplinary in nature and appears to exhibit a higher minimum scale efficiency compared with other technical activities such as customisation and applications development.

Conversely, for leaders and fast followers, a powerful strategic option is that of seeking optimal locations for R&D, based on the cost and availability of specialised skills worldwide. The scope for considering this option, however, has been limited by unwillingness to challenge the status quo and poor knowledge of what is happening elsewhere. Unfortunately, technology-related incentives to set up fully-fledged machine tool R&D facilities in the UK are nowhere nearly as attractive as in say pharmaceuticals and chemicals, where there is a strong corporate and university research tradition and a pool of highly trained scientists at hand. Similar observations have been made in respect of weaknesses in the machine tool customer base in the UK, in which the benefits arising from user-initiated product innovation may be limited.

For explanations of the four-exceptions to the historical trend outlined earlier it is necessary to briefly comment on the divisibility of research, design and development. Machine tool manufacturers tend to be more design and development-intensive than research-intensive, and many new developments originate in component supply companies. Thus it was not surprising to find that the four subsidiaries were able to cope with their new status and responsibilities. They had maintained the critical mass of adaptive design capability necessary to handle incremental product innovation and were among the most capable at purchasing, subcontracting, key component manufacture and assembly. At the time of writing, it remains to be seen whether these policy changes represent a "world product mandate" of the kind found in groups such as IBM and Hewlett Packard, or whether they are pursuing 'multifocal strategies', decision by decision. This point is important because specialisation and switches from multi-national integration towards national or regional responsiveness involve substantial trade-offs in the areas of cost, coordination and control. Furthermore, policies which delegate responsibilities and discretion to subsidiaries are difficult to reverse if they are deemed at some later stage not to have worked or external circumstances change.

4.75 Sovereignty Issues

The second part of the working propositions (ie that centralisation of R&D by foreign machine tool multi-nationals is detrimental to the UK industry) is intimately tied up with invasions of sovereignty and what is in the national interest. Macro-level interpretations are normally left to the political mechanism, moderated by the lobbying power of the industry, against a background in which the mere presence of multinationals often evokes a response somewhat disproportionate to their overall economic impact. Compelling arguments were put forward during the depth of recession that the industry was 'perilously close to collapse', moratoria on R&D expenditure were said to have 'mortgaged the future' and the strategic importance of machine tools had been ignored. To encourage inward foreign direct investment and in particular, to attract a world leader in machine tools, was a bold step by the Government, which sent a tremor through the UK and the rest of European industry.

The presence of Yamazaki will increasingly provide a focal point for debate as they move towards higher levels of capacity utilisation and the true meaning of the President's promise of full technology transfer is revealed. The plant is state-of-the-art in both product technology and manufacturing technology. There is no reason to believe that the parent company will not update the technology as it unfolds. The "demonstration effect" of the plant is highly beneficial and has forced indigenous manufacturers to reconsider their competitive position in the light of Yamazaki's openly declared intention to increase its UK market share in CNC lathes to about 20 per cent and machining centres to 30 per cent. The absence of an integrated R&D or production engineering function remains the most contentious issue and little is known of their future plans in supplying flexible manufacturing systems. There will always be those who cry "Trojan horse" but no adequate answer was forthcoming in this study to the question: what company, other than Yamazaki, would have had the ambition to invest £35 million in the UK machine tool industry at a time when levels of profitability were at an all-time low?

4.76 The Generation and Commercialisation of Technology

Much of the discussion under this proposition has focussed on the location of R&D activities by machine tool multinationals; mainly because industry experts, government officials, and executives in both parent companies and subsidiaries, regarded this as important aspect of inward foreign direct investment. At times, this bears a striking resemblence to the polarised views of technology supplier versus recipient found in the literature on developing countries! While only a small minority of opinion leaders could be accused of perceiving R&D as an end in itself, there is persuasive evidence that greater attention has been paid to the "generation" of technology than its "commercialisation". As David Fishlock (Financial Times, 20/12/88) succinctly put it:

> 'The lesson for a technology-based business is that it is more important to have technology when it is needed, than to worry about where it comes from. It can be a hard test of research management, however, to reconcile this fact with the pride of a business's own scientists and engineers.'

In conclusion, the first part of this seventh and final working proposition is accepted and the second part tentatively rejected. There is little convincing evidence to suggest that centralisation of research, design and development facilities overseas is detrimental to the UK machine tool industry. The point needs to be underlined that it is the rate at which technological advantages, irrespective of source, are embodied into products and processes that influences growth rates.

5. WIDER IMPLICATIONS FOR INTERVENTIONS

5.1 A SUMMARY OF THE RESEARCH FINDINGS

The picture emerging from this research is of an industry in long-term decline and in need of regeneration. Working from the assumption that a broadly-based machine tool industry is desirable, the research has examined various strategies for restoring international competitiveness at the level of individual business units.

The following conclusions have been drawn from analysis under the seven working propositions:

(a) There is an urgent need to challenge the set of beliefs and values pervading "product-driven" machine tool SBUs. This is not to suggest that there is something intrinsically wrong in striving for distinctive competence in product engineering. But serious problems were shown to arise when deeply rooted imbalances lead to neglect of other functional inputs and there is a tendency to cling to outmoded assumptions of market reality.

(b) The strength of the prevailing product-driven paradigm was found to be a pervasive influence on technology strategy development, most notably in the diagnosis of technological deficiencies and receptivity to particular strategic options.

(c) Considerable "potential" exists for supplementing indigenous machine tool technology with foreign technology as a strategy for catching up on international best practice. The managerial problem lies in realising this potential given that it represents a challenge to self-sufficiency in technology and threatens the status quo.

(d) Inward direct investment by foreign owned machine tool multinationals has brought substantial benefits to the UK industry. That parent companies decide the location of their R&D facilities and seek to control exploitation of their technology is their own concern. This must be set against the benefits accruing to UK subsidiaries from access to parent company technology and their customer base. The last point is often under-rated, especially when assessing the relative merits of Japanese and US participation in UK industry. While some US machine tool manufacturers may be in poor shape, the US is still a dynamic economy and remains in the forefront of developments in CAD/CAM, applications software and management techniques.

(e) Inward licensing opportunities will continue to arise in machine tools because of the fragmented nature of the industry and the relatively small size of manufacturers worldwide. There will always be a large pool of foreign manufacturers willing to share their technology without the strings attached to ownership or other equity arrangements. Taken on its own, inward licensing is about buying lead time to pursue a follower strategy. For fast followers or those wishing to stay a comfortable distance behind the leader, licensing provides a quick way of repositioning in existing product/market segments or diversifying into growth segments. For aspiring leaders, licensing is the first step in the catching-up process. Leaders continue to move forward and the only sure way of keeping abreast of them, and eventually displacing them, is to generate state-of-the-art technology yourself.

(f) Joint ventures offer an alternative to inward licensing, mainly in cases where the technology is complex and/or unfolding and where the partners wish to have a greater say in commercial exploitation. The limited experience of joint ventures in machine tools may be mainly attributed to reluctance on the part of both US and UK executives to enter into equity arrangements and almost certainly to their ignorance of what joint venture strategies entail.

(g) Each mode of technology transfer above involves different formal hierarchial structures, mechanisms and legal obligations. Ownership was found to facilitate a more enduring relationship and speed up the transfer of tacit state-of-the-art know-how. Beyond this, the actual day-to-day transfer of technology was remarkably similar in each mode, with the role of senior executives noted as a key factor in promoting/retarding interaction.

(h) The composition of packages of technology in each mode of transfer tended to be biased towards product-related know-how, reflecting the influence of the product engineering function during negotiation, transfer and assimilation.

(i) Concepts of internal organisational integration and external integration through strategic alliances with suppliers/customers is not well developed in the UK machine tool industry. Consequently, though considerable learning had been gained by UK staff exposed to Japanese operations, some of the competitive advantages related to infrastructure were not transferable.

(j) Two pre-requisites for successful inward technology transfer strategies identified in this research were: firstly, the importance of analysing competitor activities and closely monitoring technological developments worldwide; and secondly, the need to maintain a "critical mass" of indigenous skills and capital investment at various receiving points within the organisation.

5.2 IS THERE A ROLE FOR UK GOVERNMENT?

Throughout the 1980's the UK Government has adopted broad measures to restore competitiveness, showing a marked aversion for sector strategies and increasingly promoting the notion of an "enterprise culture". Compared with earlier decades, structural intervention has been minimal. Instead, the Government, through the Department of Trade & Industry (DTI), has preferred to stimulate awareness of various "enabling" technologies and to partially fund innovation. On occasions, it has also been prepared to "open doors" and act as a marriage broker to facilitate inward foreign direct investment and collaboration. No special treatment has been forthcoming to the machine tool industry. Any UK-based company eligible to take up the schemes could do so and the general message continues to be: "problem ownership lies with individual companies".

It was not initially intended in this research to examine whether greater Government intervention is desirable; nor to speculate on what mix of foreign direct investment, collaboration and indigenous technology would be tolerable in the party political sense. The machine tool industry, however, is firmly in the political arena for two main reasons: (a) senior executives and politicians have vivid memories of the Industrial Reorganisation Corporation (IRC) and the subsequent demise of Alfred Herbert as national champion, and (b) there have been calls for protectionism to reduce Japanese imports and a controversial subsidy was given to Yamazaki's investment in a UK manufacturing plant. In the case of the IRC and Alfred Herbert, there is fair consensus of opinion among all stakeholders in the industry that this was Government intervention at its worst and should not be repeated. Recent experience of similar intervention in the French industry reinforces this view.

Though observers often point to the Japanese model of government intervention, economic development and inward technology transfer; it is time-bound and unrealistic in the UK context of the 1980's in three key respects: (a) the Japanese Government cacooned their machine tool industry in import tariffs and quotas, (b) they excluded inward foreign direct investment, and (c) they closely controlled the type of technology selected for indigenous development and acquisition. Protectionism beyond the imposition of the "voluntary" limit on imports would be anathema to current Conservative party ideology. While formal tariffs or quotas may gain a temporary breathing space for UK-based machine tool manufacturers, there is a strong argument that such action would penalise machine tool users and be impossible to enforce within the EEC. On the wisdom of attracting a major Japanese producer, the same arguments are appearing as when the first wave of US machine tool manufacturers came to Europe in the 1950's and 60's. Opinion is divided between those who are affected directly and those who, after weighing the pros and cons, marginally favour Japanese plants sited in the UK than elsewhere in the EEC.

It must be concluded from this research study that executives would not welcome more direct "hands on" intervention from Government, such as might be implicit in sectoral planning and subsequent rationalisation of the industry. In contrast, DTI initiatives such as "Support for Innovation" and its successor, "Research & Technology", have been received favourably; suggesting that there is considerable opportunity for government and industry to jointly devise schemes which build on past successes. The following criticisms concerning DTI initiatives emerged from this research:

(a) Most DTI schemes have emphasised "technology push" to the relative neglect of market aspects of technology. Applicants for funding are required to establish commercial viability of their proposals; but in many cases, market surveys lack substance and have been used to justify product decisions already taken. This is notoriously difficult for an external assessor to detect. Nevertheless, more detailed scrutiny of market potential and the resources allocated to commercial exploitation and sustaining presence in markets should be a feature of future initiatives.

(b) DTI advisory schemes have remedied temporary shortfalls in key skills (eg marketing, design, quality) and many executives took advantage of this form of subsidised consultancy. This seems to be as far as the DTI is prepared to go in the skills area; mainly leaving continuing education, training and human resource issues to other government departments or individual companies. Such fragmentation is partly responsible for the poor appreciation of managerial components of technology.

(c) In cooperation with UK commercial attaches and counsellors in foreign countries, notably the US and Japan, the DTI provides an excellent business intelligence service for companies wishing to locate potential partners overseas. For those who have not sought assistance, a perceptual problem must be overcome: executives are often reluctant to involve themselves with bureaucratic government departments and are put off by their inability to offer "problem-specific" assistance. Consequently, the service is under-utilised and mis-represented. The spectre of Europe 1992 provides a testing example of DTI accessibility and further judgement will be made by executives on its ability to live up to the claims of its promotion campaign.

(d) Two further operational factors continue to inhibit the effectiveness of DTI intervention: firstly, the lack of continuity of staff and schemes; and secondly, the requirement for staff to be active across too many fronts. Many executives praised DTI officials for their competence and tenacity against adversity; but there was an over-whelming feeling that as soon as experience is accumulated, officials will be moved on and schemes substantially modified or abandoned. The five-month moratorium placed on financial support for innovation in 1984/85 is a case in point. My own dealings with DTI officials throughout the 1980's confirm this view.

The main hope for DTI intervention lies in the opportunity for officials to become more attuned to the kind of strategic problems facing particular groups of companies. In this sense, it is suggested that the classification "machine tool industry" may be redundant and have led to partial views of competitiveness. Rethinking competitive situations in more holistic terms, such as networks of relationships, may well provide a better focus on individual inputs and interactions than the arbitrary notion of an industry. Grouping machine tool manufacturers, users, systems integrators, specifiers, sub-contractors, component suppliers, etc., would be a useful starting point. To-date, the motor vehicle manufacturers and Government defence procurement executive have used their purchasing power to convene such groupings. There are many other smaller groupings with less dominant lead users which would benefit from external intervention to provide a forum for discussion and to stimulate collaboration. This is consistent with DTI initiatives in "enabling" technologies and does not treat technology in isolation from context and environment.

At the time of writing, the Research & Technology initiative is turning more towards funding collaborative ventures, particularly within the EEC. It is imperative that DTI officials understand the antecedents to collaboration and the sensitivities underlying any attempt to prise machine tool manufacturers away from their narrow concept of machine tools as metal cutting/forming/handling devices. The last point is not just a question of "systems thinking" related to the convergence of technologies, it is part of wider problems of strategic re-orientation and internationalisation of markets.

5.3 IS THERE A ROLE FOR INDUSTRY-LEVEL ORGANISATIONS?

Following on from the previous discussion, it would appear that the gap between Government and individual manufacturers is wide. Indeed, at several points in this study, the roles of industry bodies such as the Machine Tool Trades Association (MTTA) and Machine Tool Industry Research Association (MTIRA) have been criticised for their fragmentation and lack of lobbying power; and wider representation through the National Economic Development Office (NEDO) and the now defunct Manpower Services Commission (MSC) for failing to provide any real dialogue with Government. The MTTA has provided a poor service to its members and vice versa. Its inability to resolve the continuing dilemma of simultaneously voicing the views of both indigénous manufacturers and importers has won it no friends. The MTIRA has belatedly widened its scope into user problem-solving, thereby placing it in competition with other research associations; but the separation of commercial and technical representation remains questionable in the competitive climate anticipated in the 1990's.

A cursory examination of various industry bodies immediately reveals that most exist to promote sectional interests. In contrast, NEDO is worthy of special mention because, like the MSC, it was set up as a tripartite organisation comprising government, industry and trade unions. Despite criticism of its Sector Working Parties degenerating into a 'talking shop' and their 'lack of teeth', NEDO is one of the few organisations to have approached strategic issues in a balanced way. It has commissioned a number of excellent industry reports in the past and in 1989 launched a useful diagnostic aid to company performance called "The Innovation Management Tool Kit". Unfortunately, the Conservative Government has not embraced the philosophy of NEDO and its future, at least in its present form, seems uncertain. Similar political uncertainty surrounded the MSC and Industry Training Boards which also suffered from the lack of staff continuity and diluted effort characteristic of the DTI.

The principle of placing problem ownership with individual companies is sound in theory but what if executives do not recognise that they have a strategic problem? Whatever the party political stance, there is a need for an adequately funded, stable body, independent or quasi-government, which carries sufficient credibility to act as an external catalyst for change and is able to coordinate a campaign to stimulate strategic reorientation. Taking into account all facets of the need to tackle the product-driven paradigm in machine tool manufacturing SBUs, the external body most likely to succeed is the Engineering Council (EC).

The EC was set up within the period of office of the present Government and thus carries political acceptability. It is an existing body representing professional and technician-engineers, thereby obviating the creation of a new body which might take a long time to set up and only increase fragmentation. The EC has within its terms of reference: general management capability and the effective use of design, production and marketing resources. It is already successfully promoting multi-disciplinary approaches to international competitiveness and continuing education for managers, and specifically, the use of the "technical review" as a planning tool for which it has received DTI funding. Any initiatives in management development would necessarily have to be aimed at the broad range of engineering industries to attract Government funding, rather than narrowly targetted at machine tools. There is no reason to believe that other engineering industries have a lesser need. The EC is well placed to penetrate individual companies because it can use professional identity as a platform for intervention. The Director General is known to be sympathetic to this view and willing to work alongside industry bodies such as the MTTA and centres of excellence in the organisational development field.

5.4 INTERVENTIONS AT CORPORATE LEVEL

Investigation of the corporate/SBU interface was highlighted as an important shortcoming of this study. The more this interface was probed, the more the methodology appeared inadequate for handling the complexity and dynamics of relationships. The residual feeling, having completed research in the 75 per cent of SBUs in which this was relevant, was one of having merely scratched the surface.

A sufficient number of issues emerged to indicate that this is a fertile area for further research, with the related topics of corporate/business planning systems and capital investment decisions offering possible vehicles for in-depth analysis over time. Such research might, for example, explore propositions on the composition and political behaviour of corporate and business unit boards of directors, the compatibility of financial and technological criteria, and various inhibitors to strategic choice and resource allocation. This would almost certainly require re-opening the debate on the appropriateness of SBUs in a dynamic economic and technological environment.

One particular topic worthy of empirical research at the corporate level is the possibility that changes of ownership and/or management may facilitate strategic change. Incoming owners/managers typically possess a legitimate mandate for change, at least for a limited period. Having rejected direct Government intervention in restructuring the industry, then any changes must either be left to market forces or await corporate responses such as divestment of SBUs to more dynamic owners and management buyouts. It is possible to point to two successful buyouts in this research (Verson International and Bridgeport) and several others in which the experience has been mixed.

5.5 INTERVENTIONS AT BUSINESS UNIT LEVEL

There is little doubt that machine tool manufacturing companies in the UK are in need of strategic reorientation. The traditional prescription for achieving this reorientation would be to devise some form of organisation/management development programme based largely on team building. Such programmes typically commence with an exploration of the prevailing attitudes, values, beliefs and aspirations held by senior executives; aimed at establishing their dominant "world view". It would then be necessary to use various re-framing and surfacing techniques in order to challenge deeply rooted assumptions underlying their conventional wisdom and move towards a shared vision of the future. Beyond this, generalisations are unhelpful and the appropriate intervention must take into account differing magnitudes and time scales of the task, receptivity towards change and the capability of senior executives to manage change programmes.

The difficulty in machine tools lies in bringing about change in an industry possessing a poor record of investment and struggling to attract high calibre people. Yet beneath this depressing facade, my research has identified pockets of capability and enthusiasm waiting to be released. Indeed, I was frequently impressed by the outstanding abilities of certain individuals across the full range of SBUs. They were to be found in general management, in all functions and at all levels, no matter how progressive or laggardly the SBU overall. Within their own function, these same people often showed a remarkable capacity for improvisation, as evidenced in their response to customisation and tenacity to make things work under severe resource constraints.

Many observers have tended to view this propensity for improvisation in a pejorative way (ie as indicative of sloppiness, inconsistency and out of control). Viewed from another angle, this represents tolerance for adaptation and these people may be the potential catalysts for change. Their location in the organisation would emerge from an audit of human resources. The organisational development task would then become one of releasing stored up energy in an organisational setting in which others around them, including senior executives, may not necessarily perceive there to be a problem. This again highlights two facets of strategic management capability: (a) problem recognition on the part of top managers, which may require an external stimulus, and (b) the ability to diagnose and manage sensitive socio-political processes. Two exemplorary cases of strategic reorientation were found among machine tool manufacturers (ie Verson International and Bridgeport) and there are parallel developments taking place elsewhere which provide external benchmarks as well as grounds for optimism.

Take, for example, attempts by ICL to build general management skills and improve communication across functional interfaces. One simple feature of ICL's development programme has been their encouragement of multi-disciplinary teamwork and 'co-location' through bringing people in different disciplines together in close geographical proximity. Similar interventions involving team building are known to be proceeding successfully at Lucas Industries. At Honeywell Bull and Black & Decker I have inside knowledge of what can be achieved in changing internal culture to accept the implementation of organisation-wide systems such as marketing planning, quality management and customer service. The common ingredients of success in these two companies would appear to be: (a) a clear vision of what is required in business terms, (b) top management involvement in implementation, (c) detailed attention to responsibilities, procedures and re-training, and (d) a sense of leadership by top management. Clearly, these limited examples suggest that executives in machine tool manufacturing companies must be urged to widen their domain and learn from experiences elsewhere. Closer relationships with some of their more progressive customers and suppliers would provide a useful starting point.

5.6 INTERVENTION AT FUNCTIONAL LEVEL

Team building within functions might improve hierarchical communications and facilitate a more focussed approach but there is an inherent danger in pursuing this line too far in that greater cohesiveness may merely reinforce existing values and beliefs. Without an infusion of new blood and extensive personal development of existing staff in some SBUs, improvements in effectiveness may be impossible or simply take too long. This is not to advocate "scare tactics" but more drastic measures are necessary in some long-established SBUs to eradicate complacency before the next downturn in the economy.

Functional interventions, therefore, should centre on the need for continuing education, retraining and recruitment of staff. While this calls for management and personal development programmes of a highly situational nature, several common themes may be highlighted:

(a) Engineering/Technical Function: The priorities for development of product engineers in most SBUs are managerial rather than technical. Keeping abreast of technical advances is vitally important and there will always be a need for technical updating. The problem is that much of the progress has been fragmented and of questionable cost-effectiveness. Product engineers must be encouraged to scan external developments on a wider front and become more receptive to international sources of technology. There is little point in allocating scarce resources to projects which reproduce what is already available quicker and cheaper elsewhere.

The cost of the product engineering activity in machine tools is small in relation to its impact on the overall business. Product engineers need to become much more aware of their cross-functional responsibilities and their contribution to competitive advantage. There is an urgent requirement to manage the conversion of technical success into commercial success.

(b) Marketing/Sales: Staff in this function were heavily criticised for adopting a tactical role and their lack of professionalism. The skills deficiency is widespread in the industry and requires a more determined effort to raise standards than is possible through DTI consultancy schemes. Market research, commercial negotiation, product/market segmentation and positioning stand out as priority areas, especially in small SBUs operating in multiple niches. While most executives had conducted market surveys of some kind prior to the introduction of new models, little attention was paid to customer-based perceptions of product attributes/benefits and competitor dynamics. It should be noted that weaknesses in competitor analysis have a dual effect in the context of this research: knowledge of competitors is essential not only to identify and exploit differential advantage, but also to identify potential partners for collaboration.

Marketing was at its worst in companies drifting towards higher levels of customisation where, despite widening product/market scope, there was a tendency to think of differentiation as unchanged and for it to be subsumed under what they believed to be "customer-orientation". Many sales engineers, for example, were being asked to take on higher level sales development and problem-solving with little or no re-training. Nothing short of a major education and training programme will remedy these shortcomings.

(c) Production/Manufacturing: Substantial support was found for the view that the production function is inward looking and carries low status, that managers join the strategy debate late and this puts them in "response mode". It is possible to state with confidence that in most SBUs the quality of representation at board level left much to be desired. Few production directors appeared to play an active part in strategy formulation. They offered little direction and their managers were invariably involved in "firefighting", feeling unable to find a way out of their short-term predicament. The presence of certain competent individuals in key jobs was observed to lift the status of production/manufacturing from its generally low level throughout the industry. Upgrading the quality of production management and manufacturing systems expertise is deemed to be critical, whether pursuing strategies based on low cost production of standard machines or cost containment in customised machines.

Many of the aforementioned deficiencies can be alleviated by selective formal business training, either via open or in-company programmes. A less tractable problem is the downward spiral in which executives are reluctant to instigate internal retraining, fearing loss of key staff such as sales engineers, manufacturing systems engineers, software specialists, once they have updated their capability. Yet at the same time, these executives were found to be poaching staff from competitors and other engineering companies. This is a national problem, extending beyond the remit of the current research. The serious implication for machine tool manufacturers is that they are perceived to be among the least attractive employers for the range of commercial and technical skills in most demand. Once again, Government intervention is required to break the spiral, anticipate future problems and initiate training programmes.

6. RECOMMENDATIONS

6.1 RECOMMENDATIONS FOR UK GOVERNMENT:

(a) Continue the policy of minimal structural intervention, emphasising the Government's role of creating a social/industrial climate conducive to change, offering selective support for awareness campaigns and the adoption of "enabling" technologies.

(b) Department of Trade & Industry (DTI) initiatives should place greater emphasis on market feasibility and the "application" of machine tool technologies.

(c) International aspects of business should permeate all DTI initiatives. This to include a higher profile for the Overseas Technical Information Unit, improved collation of international statistics, special funding for overseas industry tours (especially for young managers).

(d) DTI "Enterprise" schemes should be extended to include consultancy on technology acquisition/transfer. This is especially important in the case of small companies. The Support for Innovation scheme requires extension of its current limited scope of intra-EEC collaboration, to include collaboration with any appropriate foreign partner.

(e) The DTI should convene "market development" seminars on issues of current interest to particular groups of companies. These could include : joint ventures within the EEC, export consortia approaches, market intelligence, Eastern Europe etc.

6.2 RECOMMENDATIONS FOR INDUSTRY ORGANISATIONS:

(a) The Engineering Council (EC) must take a stronger role in the professional development of its members in the spirit of the Finniston Report. The EC should raise its visibility as the national body representing professional engineers by campaigning for additional funding and proposing selected interventions aimed at the regeneration of key sectors of engineering. Such interventions should be primarily focussed on training and developing the human resource base.

(b) The Machine Tool Trades Association (MTTA) should merge with other related organisations such as the Advanced Manufacturing Technology Research Institute (formerly Machine Tool Industry Research Association), British Robot Association, Metal Forming Machinery Makers Association, Association of Machine Tool Merchants, Production Engineering Research Association etc. Industry representation in the UK is too fragmented. The ultimate model is the powerful Verband Deutscher Maschinen-und Anlagenbau (VDMA) in West Germany.

6.3 RECOMMENDATIONS FOR MACHINE TOOL MANUFACTURERS:

(a) The first priority is for chief executives, managing directors and divisional directors to take a more strategic approach to their role as general managers. This quality, of thinking and acting strategically, is a pre-requisite to effective and efficient business operations. The leading business schools cater for this need in their senior management programmes.

(b) General management capability must be developed among functional directors, not only because they carry board level responsibilities but also to aid succession planning. This could be handled pro-actively by participating in some combination of "open" or tailored in-company programmes offered by business schools and seconding staff to special assignments of a business development nature.

(c) Management training for executives and senior specialists in the three main functions of sales, product engineering and production is required to break down barriers at functional interfaces. This would normally involve teambuilding and inter-personal skills training as part of an integrated management/organisational development programme.

(d) There is a need for managers at all levels to become more internationally-orientated. Foreign parents/subsidiaries, licensors/licensees and joint venture partners possess the opportunity for an interchange of staff. UK companies with no formal overseas contacts must encourage visits to international trade shows, export tours and participation in overseas trade delegations. In-company workshops and briefings on international business are also useful ways of exposing staff to recent developments. Specifically, deficiencies have been identified in the areas of EEC competition law, intellectual property, joint venture strategies, commercial negotiation skills and languages.

(e) At the functional level, priority should be given to general marketing and manufacturing engineering skills.

The recommendations from this research may be generalised to product-driven manufacturing companies in certain other engineering industries (eg capital equipment manufacturers in printing, textiles, mining, food processing, chemical processing, etc). These are highly cyclic and heterogenous industries in which product specifications and varying degrees of customisation are typical. It should be noted that much of my recent professional activities are in these types of company. Less confidence is attached to expectations of similar behaviour in larger companies in mass produced standard products (eg motor vehicles, consumer electronics, white goods) where sales and production may well dominate internal power relationships.

APPENDIX A DETAILED METHODOLOGY

This Appendix provides supporting data on the research sample and questionnaires outlined in Section 3.

A.1 THE SAMPLE OF MACHINE TOOL MANUFACTURERS

The exploratory research study identified 330 suppliers of machine tools in the UK in 1984, of which 205 could be classified as manufacturers. These manufacturers are broken down into the five technological segments in Table 19:

Table 19. Breakdown of Suppliers of Machine Tools By Machine Tool Technology for the Years 1979 and 1984

	Estimated Number of Suppliers in UK		Estimated Number of Manufacturers in UK	
	1979	1984	1979	1984
Turning	185	150	80	47
Milling	161	149	58	30
Grinding	116	114	38	29
Metal Forming	112	70	53	34
Automation (inc. robots)	132	251	111	195
Total	351	330	221	205

Notes : The term "suppliers" includes all import distributorships, sales subsidiaries of foreign manufacturers, and UK-based manufacturers. It should be noted that some UK-based manufacturers hold distributorships. By example, the above table should be read as follows: there were 150 suppliers of turning machines in the UK in 1984, of which 47 were manufacturing in the UK.

Source: Directories, Trade Show Handbooks, Direct Mail Lists.

From the population of 205 manufacturers, 65 were approached in the course of this research, of which 54 agreed to cooperate. The breakdown of the sample by UK and US ownership is shown in Table 20. A further breakdown by machine tool technology is presented in Table 21.

Table 20. Breakdown of Sample of SBUs by Ownership and Response

	Sample Size of SBUs	Number of SBUs Interviewed	Response (%)
UK-owned SBUs	46	36	78
US-owned SBUs	19	18	95
	65	54	83

From Table 20 it can be seen that the response rate in the case of UK-owned SBUs was lower (78%) than with US-owned SBUs (95%). This may be attributed to the generally higher level of interest in international technology transfer in the latter and, possibly, their prior knowledge that I would be visiting the USA at some later date.

Table 21. Breakdown of Sample of SBUs by Ownership and Machine Tool Technology

	UK-Owned SBUs	US-Owned SBUs	Total
Turning	11	8	19
Milling	9	7	16
Grinding	7	3	10
Metal Forming	7	4	11
Automation	12	6	18

Notes : (a) 18 SBUs in the sample were manufacturing machines in more than one technological segment.

(b) 20 of the 36 UK-owned SBUs had contractual links with foreign companies for the inward transfer of technological know-how.

(c) 16 of the 18 US-owned SBUs had formal inward marketing and manufacturing agreements with their parent company and 3 SBUs had agreements with unrelated licensors. The parent company of one SBU was not active in machine tool manufacture in the USA.

A.2 THE NON-RESPONSE

The following reasons were given by executives in the 11 non-responding SBUs for not wishing to be interviewed:

(a) One managing director and one divisional director politely refused due to 'pressures of work'.

(b) Two managing directors and one divisional director (in the only non-responding US-owned SBU) did not actually refuse but showed their reluctance by giving a series of excuses over the telephone as to why an interview date could not be given. These companies were known to be in strategic trouble. One further company was placed for sale in late 1984 and another went into receivership within three months of last contact.

(c) One managing director of an SBU active in licensing replied immediately in writing that:

> '....it is not our policy to divulge details of our license arrangements under any circumstances ....Our only comment would be that we have had numerous license agreements over the past 30-35 years in many different areas of technology. We have always found them successful where they have given the licensor access to a satisfactory revenue and ourselves access to good technology at a price cheaper and less risky than internal development'.

(d) One managing director said that inward licensing was not relevant to his company's operations and he had no interest in my research programme.

(e) An interview with one managing director was arranged and later cancelled due to the company calling in the receiver after the date had been agreed. I was turned away at the factory gate. Three other SBUs had been selected in the sample but went into receivership before being approached.

A.3 HOMOGENEITY

During the first stage of interviews it was possible to meet the Head in 45 of the 54 SBUs studied, representing 82 per cent of the target respondents. This is considered to be a set of respondents of acceptable homogeneity. Second and third choice respondents were the engineering/technical director and marketing or manufacturing directors respectively.

In only 3 cases was the true Head of the SBU wrongly identified initially. This became apparent during questioning, when it was clear that strategic decisions were made at a higher level. The material from these interviews was relegated to background information and personal interviews held at a later date with the appropriate person.

In 2 cases the Head of SBU was deliberately not interviewed because they were recent external appointments and deemed to have insufficient knowledge of the company and industry to provide meaningful answers at that time.

Of the 4 remaining Heads not interviewed, two were regarded by their senior managers and sales representatives as 'inaccessible' to outsiders such as academics and the press. The remaining 2 Heads were absent from the office over the period when I had grouped interviews for geographical convenience. None of these 4 Heads was averse to allowing senior colleagues to be interviewed.

A.4 MODES OF INWARD TECHNOLOGY TRANSFER

The research was restricted to the "inward" flow of foreign machine tool technology into the UK via three formal modes - direct investment, joint ventures and licensing arrangements. Other transfers may result from the outright purchase of technology, consultancy, technical service agreements, subcontracting etc., and indirectly through technology embodied in imported machines, components and equipment. Indirect transfers were considered only when they formed a vital contribution to formal technology packages. Conceptually, all three formal modes of transfer have one theme in common - the inward flow of technology.

Research of this kind does not have a tidy starting point. It involves intervention and picking up the threads of continuing relationships where there is cumulative experience and "sunk" costs of setting up subsidiaries, joint ventures and licensing arrangements. Moreover, each of the three modes require investigation of the role of foreign ownership and control: (a) because these constrain strategic choice; and (b) since industrial property rights are involved, there are implications for the "permanence" of technology transfers to the UK. The classification of transfer modes is not a simple process. It is more realistic to view transfer modes as lying on a continuum, with the possibility of equity participation and various contractual arrangements existing in all three modes as follows:

(a) Licensing is a negotiated "leasing" arrangement for the transfer of technology rights between the foreign supplier (licensor) and the UK recipient (licensee). The two parties are normally independent, giving an "arms length" relationship. They may also be related by small equity stakes and, in some cases, may share technology by entering into cross-licensing agreements.

(b) Joint ventures are negotiated collaborative arrangements which may be of a contractual nature and/or involve the formation of a joint company with various levels of equity holding. Executive control may reside with the dominant share-holder but this is often offset by the technology-contributing partner retaining ownership of the technology rights by licensing the joint company.

(c) Direct investment involves the "internalisation" or intra-company transfer of technology. Foreign parent companies and their divisions frequently operate licence agreements or management/ technical service agreements with their UK affiliates. Even though the UK recipient may be a wholly-owned subsidiary, the separation of ownership of the technology is claimed to be desirable by foreign parent companies to preserve autonomy among divisions, to provide a channel for the remission of royalties (irrespective of whether the subsidiary is profitable) and as a safeguard against the nationalistic tendencies of host governments.

A.5 QUESTIONNAIRES AND LISTS OF DISCUSSION ISSUES

A.51 Semi-Structured Questionnaire Used With All Heads of SBU

Preamble: describe my personal background/experience. Outline the research brief: emphasise confidentiality, anonymity and non-alignment with competitors.

Would you please describe your company and its activities? (eg ownership, structure, organisation at board level, functional responsibilities, age/experience/education of board members, events that have shaped the company and its direction)

How many people were employed by your company:
(a) in mid-1979 (pre-recession) (b) at date of interview?

What are your main products? (order of importance)

Who do you regard as your main competitors? (national, international, order of importance, probe knowledge of competitors and how they are monitored)

How often do you hold formal board meetings? (explore who attends, length of meetings, interaction, importance of informal meetings)

What items would typically be on the agenda? (request example of last meeting, note top five items)

Has the agenda changed much in recent years? (impact of recession, financial pressures, introducing new technology)

Do you have formal business planning procedures? (existence of document, standard format, time horizons, performance criteria, who coordinates the plan)

In what way is technology introduced/discussed at board meetings?

What are your company's current technological strengths?

Have there been any significant breakthroughs in technology in your company over the last five years? (examples, perception of leadership/followership)

What technological strengths will your company need in say 10 years time?

What do you find is the main constraint on your company in keeping abreast of technological developments? (request examples, how does he monitor technological change)

How important are inputs from your component suppliers and sub-contractors? (examples)

How important are inputs from your customers? (examples, importance of specifications/procedures)

How do new products typically start off in your company? (examples, time scales, product/process development, market research)

Is it necessary to have an order before you start the design of a new product? (extent of standardisation/customisation, cash constraints)

Have you considered and/or taken up any of the DTI's financial support schemes for product design/development?

Has the DTI's SEFIS II scheme proved useful to your company in stimulating demand?

Are "experience/learning" curves important in your operations? (explore views on cost reduction)

Do you think that "reverse engineering" is prevalent among machine tool manufacturers? (explore value engineering/analysis)

Do you manufacture overseas?
If yes, through wholly-owned subsidiaries, parent company, associate companies, joint ventures? (countries)
If no, explain why not (any bad experiences)

Do you export overseas?
If yes, through wholly-owned sales offices, parent company, associate companies, joint ventures, agents/distributors? (countries)
If no, why not? (any bad experiences)

Do you hold import agencies/distributorships?
If yes, for which products and countries?
If no, why not? (any bad experiences)

Are there any other factors that impinged on your decision to take an import agency? (consideration of alternatives, eg developing their own product, inward licensing, acquisitions)

Do you have any policy guidelines on the acceptable mix of manufacturing/export/import operations?
(corporate constraints)

How often have your Board members made overseas visits in the past two years?

	To Europe	To Japan	To USA
Managing director:	.....	.....	.....
Marketing/Sales director:	.....	.....	.....
Engineering/Technical director:	.....	.....	.....
Manufacturing/Production director:	.....	.....	.....
Others:	.....	.....	.....

Did your company exhibit or send delegates to any of the following recent trade shows?

	As Exhibitor	As Visitor	Number of Delegates
Chicago:	.....	.....	.....
Hanover:	.....	.....	.....
Osaka:	.....	.....	.....
Paris:	.....	.....	.....

A.52 Semi-Structured Questionnaire Used With UK Heads of SBU Only.

The British Government is encouraging direct investment by foreign machine tool manufacturers in the UK. Is this a good thing for the home industry?

Inward licensing and other forms of collaboration are also being encouraged. Are these worthwhile?
(a) to the country (b) to the licensee?
(probe respondent's knowledge of UK licensing activities)

Is your company: (a) a licensee, (b) a licensor, (c) a partner in cross-licensing, (c) a joint venture partner?

Should the British Government act as a technology "marriage broker" in some way?

A.53 Semi-Structured Questionnaire Used With Heads of UK Subsidiaries of US Parent Companies Only

Is there a licence agreement in existence between your division and your US parent company? (any other form of agreement, eg management/technical)

Are you required to take on your parent company's product designs and know-how? (explore standardisation/customisation of designs, interchange of staff, value of know-how)

Do you pay your parent company a royalty or some other fee on the technology?

Is the flow of expertise one-way or both ways?
(test perception of "poor relation", examples of inward/outward flow of

know-how, cooperation/conflict)

Are you free to look outside your parent company for technology? (examples)
If yes, does your parent company impose criteria?
If no, how do you feel about this constraint?

Have there been instances of technology originating elsewhere in your Group being transferred to the UK (eg form a sister company, central R&D laboratory)?

A.54 Record of Inward Licensing

Licensee: ....
Licensor: ....
Products/processes:..........
Year of signing:..........
Duration:..........(inc. extensions)

Who is responsible for licensing in your company (job title)?

Who negotiated the agreement?

How did you know that the technology was available through licensing?

Who instigated the licence:
(a) your own company, (b) the licensor, or (c) other?

How many potential licensors were there?

How many licensors did you assess:
(a) initially, (b) short list?

What particular features of the licensor attracted you to them?

What particular features of your company do you think made you attractive as a licensee?

Why did you seek a licence?

Which of the following items are covered by the licence?
(a) patents, (b) trade marks (licensor's mark, joint mark, own mark), (c) designs, (d) know-how, and (d) other (name).

Form of payment:
(a) down payment, (b) progress payment(s), (c) single payment for full package, (d) minimum royalty, (e) running royalty (basis for calculation), and (f) fixed sum per unit of output?

Is there in existence a separate technical service or management contract?

What territorial restrictions has the licensor imposed? (eg exclusivity in manufacturing/sales)

Is there a "grant-back" clause whereby licensor and licensee agree to exchange details on product/process improvements? (examples)

Has the licensor applied "tie clauses" (inc. ex-agreement) concerning the import of key equipment, raw materials and components from himself and/or a named supplier?

Are you selling the licensed product(s) back to the licensor?

What proportion of the total manufacturing cost of the licensed product is accounted for by bought-in materials and components?

At the time of signing the agreement, had your company the resources to design/develop the product in-house?

What was the estimated cost and time period if you had opted for in-house development?

How did you assess the value of the licence package?
(explore the process of "unpackaging" and weightings attached to each component).

What was the time period from the decision to go-ahead in the product area to actually signing the agreement?

What was the time period from signing the licence to first sale of the product:
(a) for machines initially imported from the licensor,
(b) for machines assembled from kits supplied by the licensor,
(c) for machines manufactured in the UK?

What were the main problems in adopting/adapting the licensed technology? (examples)

What were the benefits? (examples)

Did the licence require expansion of your facilities?

Did the licence introduce any new methods of working? (examples)

What proportion of your total sales in machine tools manufactured in the UK is based on licensed products?

Based on your experience to-date, would you licence-in technology again?

Is your view shared by other Board members?

What would you do if the licensor withdrew the licence?

A.55 Issues Explored During Informal Interviews with:
(a) UK Functional Directors and Senior Managers, and
(b) UK Middle Managers, Sales Engineers, Applications Engineers

Experience, career progresssion, external activities, overseas visits.
Perceptions of their role.
Impact of recession, sales trends, competitors activities.
Extent of standardisation/customisation.
Cross-functional interaction.
Relationships with suppliers, sub-contractors, customers.
Product/process development.
Attitudes towards foreign technology.
Relationships with parent/licensor (where appropriate).
Content of licence agreements (where appropriate).
Evaluation/negotiation of licence agreements (where appropriate).
Technical matters.

A.56 Issues Explored During Informal Interviews With US Vice-Presidents and Senior Managers

Trends in US market.
US/UK relationships.
The technology transfer process.
Location of research/design/development facilities.
Technical matters.

APPENDIX B SUPPORTING DATA/ANALYSIS ON TECHNOLOGY STRATEGY AND INWARD TECHNOLOGY TRANSFER

This Appendix provides supporting data and analysis for the themes explored under the working propositions in Section 4, with particular reference to industry/company performance and the process of technology transfer.

B.1 THE UK MACHINE TOOL INDUSTRY

B.11 An Overview of Competitive Performance

Since approximately 40-45 per cent of machine tool production enters the world market, it is clear that the competitive performance of the UK industry must be assessed on an international basis. The following observations relate to the comparative statistics presented in Tables 39-43 at the end of this Appendix:

(a) the UK has fallen from the position of fourth largest world producer and exporter in 1965 to eigth and seventh respectively in 1987;

(b) West Germany has maintained a long term position of strength as both a producer and exporter;

(c) Japan has emerged as the main challenge to West German supremacy, largely at the expense of the USA;

(d) there has been a dramatic rise in import penetration in all machine tool producing countries, except in Japan;

(e) Japanese and West German producers have maintained a high level of patenting activity in the important US market.

Trends in the UK machine tool industry are captured in Tables 44-53. The following observations may be made on these statistics:

(a) in real terms the UK industry is in long term decline;

(b) UK production by value has fallen by almost one half in real terms since the peak year of 1969/70 and employment reduced by 56 per cent between 1978 and 1988;

(c) the UK has become a net importer from 1984 onwards;

(d) the EEC is an increasingly important source of imports and destination of exports.

Figure 4 illustrates the cyclicality of machine tool order intake, showing the peak years of 1969, 1973 and 1979, followed by considerable decline thereafter.

At the level of individual segments of the industry, it can be seen from Table 49 that UK production of turning machines has declined by 67 per cent in real terms over the 1980's, grinding by 62 per cent, metal forming and automation equipment by 54 per cent. Only the milling segment has shown recovery to the peak year of 1979/80. UK performance in turning and milling may be expected to improve substantially as the Yamazaki plant reaches its design capacity of 1200 machines per year in the early 1990's.

From the above observations it can be seen that the 1980's has been one of the most turbulent decades in the history of the UK machine tool industry. It began with an unprecedented downturn in the order cycle, followed by a period of retrenchment and then developed into a prolonged struggle to catch up on world best-practice.

B.12 The Critical Influence of Developments in Control Systems on Technology Strategy

The basic principles of the main metal cutting, forming and workpiece handling processes have been known for many years. Machines incorporating these processes have evolved partly through "technology push" by manufacturers combining the technologies of mechanical engineering, electronics and computing; and partly by "market pull" from users demanding improvements in performance and efficiency.

It was possible in the 1930's to envisage the general direction in which machine tool technologies were going and by the 1950's, the concept of the automated factory was well developed. Less clear was the magnitude and timing of investments in technology to achieve workable solutions and the rate of adoption among machine tool users.

It is not intended here to present a detailed description of the technological evolution of the industry. For the purposes of this research, it is sufficient to note that the industry has been studied by various committees and research organistions over the post-war period and several useful reports have emerged. Most reports are at a high level of aggregation but two far-sighted reports are worthy of special mention in relation to technology strategy: the Mitchell Report (1960) and the Way Committee Report (1970). Both reports highlighted the central importance of developments in control systems, a factor which subsequently had a major impact on the fortunes of the UK industry.

The Mitchell report recommended that UK machine tool manufacturers should not enter the field of electronic control systems design and manufacture. This was endorsed a decade later by the Way Committee, which noted:

(a) the future importance of 'systems engineering capability', recommending that responsibility for integration of mechanics and electronics should reside with machine tool manufacturers;

(b) that a few US machine tool manufacturers were developing control equipment in-house and a major producer in Japan had increased its output from 500 units in 1967 to 2000 in 1969.

Way doubted the UK industry's ability to keep pace with developments in electronics and hopes were pinned on the only surviving major UK control equipment manufacturer, Plessey Numerical Controls Ltd., which had been recently formed by merger of the control activities of Ferranti, Airmec and Plessey.

Although Plessey produced numerical controls (NC), and later, computer numerical controls (CNC) of its own design, its most sophisticated control systems were manufactured under licence in the UK from Allen-Bradley of the USA. Unfortunately, this arrangement only continued up to July 1979, when Plessey decided to withdraw from machine tool controls and Allen-Bradley acquired the business. With hindsight, it is tempting to speculate that with greater commitment, this arrangement might have provided the best opportunity to form an enduring strategic alliance which would have placed the UK industry in a much stronger competitive position in the 1980's.

Meanwhile, Alfred Herbert had set about jointly developing its own range of microprocessor-based controls with a small company which, despite the recommendations of the Way Report, it later bought out. On the collapse of Alfred Herbert in June 1980, the controls business was acquired cheaply by GEC. Three years later, GEC had also failed to produce a competitive control system and the UK machine tool industry was left totally reliant on imports.

The rapid adoption of computer numerical control systems as a factor in competitiveness since the mid 70's is more than adequately illustrated in Table 22:

Table 22. CNC Machine Tools as a Percentage of Total UK Production for Years 1972-1988

Year	% CNC of Total Production
1988	44
1986	35
1984	32
1982	23
1980	15
1976	8
1972	6

Source: Machine Tool Trades Association

It is against this background of national deficiency in control systems that the technology strategies pursued by UK-based manufacturers must be judged. It serves to emphasise the critical importance of monitoring technological change on a global basis and points to consideration of opportunities for strategic alliances as a means of gaining early access to new developments. The following short analysis of individual segments of machine tool technology will focus on the international dimension of technology strategy by drawing on selected cases to illustrate both the opportunities and pitfalls.

8.13 Turning Technology

8.131 Centre lathes

The volume production of turning machines in the UK is dominated by Colchester Lathes and T S Harrison, both members of the 600 Group. Their traditional strengths lie in centre lathes, for which they can probably claim 80-90 per cent of the UK market and a respectable share of export markets.

Colchester and Harrison were slow to move into CNC and hence to trade up their customer base. CNC was initially the perogative of another division (Hydro Machine Tools) and this delayed its adoption throughout the group. Even as late as 1984, they were retrofitting some of their standard models and customer perception of their product range continues to be that of a centre lathe-derived machines rather than an integrated approach to CNC.

8.132 Multi-spindle lathes

The demise of multi-spindle automatic lathes, one of the most important segments of turning technology historically, provides a powerful lesson for complacent machine tool executives. The hard truth is evident from the statistics in Table 23, which show that production of multi-spindle automatics declined dramatically over the decade 1976-86.

Table 23. UK Production of Multi-Spindle Lathes for Years 1976-1986

Year	Production		
	Units	£m	£m* (inf adj)
1986	39	4.8	3.1
1980	329	20.5	20.5
1976	419	12.4	22.2

Source: Machine Tool Trades Association
Note: * 1980=100

Inseparable from the stastics in Table 23 is the case of Wickman, which provides one of the rare examples of senior executives being prepared to comment publicly on the poor strategic management of technology in their company.

In January 1984, Allan Gormly, managing director of the John Brown Group, announced the Group's withdrawal from machine tools, tracing their failure back to the 1960's. The Wickman multi-spindle lathe business was doing well and the Group sought expansion through the acquisition of Webster & Bennett (boring machines), John Stirk (planing machines), Taylor & Challon (presses) and others. When the UK market entered recession in the mid-1970's and computer numerical control began to appear, these weaker companies were the first to be shown as outdated. Management time was concentrated on rationalising them, while Wickman's declining fortunes were read as short term. Gradually, the challenge from CNC turning machines and changing user requirements eroded demand for cam-operated multi-spindle lathes, yet Wickman management remained optimistic. Gormly said that the next phase was spent trying to solve manufacturing problems ....'without realising that the fundamental problem was technological obsolescence'.

In essence, Wickman ignored the signals on two fronts: (a) metal parts traditionally machined on multi-spindle automatics were gradually being substituted by other materials and processes, and (b) as users attempted to reduce working capital tied up in stocks and work-in-progress, they reduced batch sizes and CNC turning machines offered a more flexible alternative. Few users would doubt the performance of cam-operated lathes in batch sizes of 20,000 or more, but changeovers are cumbersome and with the domestic market largely dependent on such ailing industries as motor vehicle components, fasteners, consumer electronics, etc. It was clear that orders for new machines would never return to the levels enjoyed in the 1960's.

A former executive described Wickman as suffering from 'technological conceit'. And in similar vein, a former middle manager suggested that ....'they were in the mechanical age when everyone else was into electronics', going on to describe their West German competitor, Gildemeister, in the late 1970's, as '....strengthening up to cover all eventualities by becoming a turning specialist, whereas Wickman remained in multi-spindle machines'.

To be fair to Wickman's senior management, they had attempted, albeit half-heartedly, to offset overall decline in their automatic machines business. In 1977, for example, they had negotiated an import agency for CNC lathes from Nakamura of Japan with an option to manufacture under licence, only to be thwarted by trade union resistance which included shop stewards dictating where the machines should be made.

An arrangement was later concluded with another Japanese manufacturer, Taiyo Seiki, in 1979, whereby Wickman agreed to provide the specification and conceptual design for a CNC turning machine, from which Taiyo Seiki would then carry out detail design and build prototypes. It was put to the workforce that models would be made in the UK when the costs could be matched. After considerable re-design, about 100 machines were eventually ordered from Japan, largely based on forecasted sales to the USA. These failed to materialise due to continuing recession.

And finally, in 1982, John Brown acquired Olofsson, a reputable US manufacturer of CNC chucking automatic machines. The transfer of technology to the UK had just got underway when it fell foul of a major rationalisation programme in which the Group board declared machine tools as not one of their future core businesses.

8.133 CNC lathes and turning cells

Inspection of the financial performance in turning technology in Table 34 shows the difficulties experienced by manufacturers in generating sufficient cash to re-invest in their operations. The case of TI Machine Tools (now Matrix-Churchill) will be used to illustrate how these manufacturers slipped into "stuck-in-the-middle" strategies in the early 80's, mainly through product proliferation and failure to update their manufacturing base.

On acquiring the lathe business of Alfred Herbert from the receiver in 1983, TI Machine Tools's managing director boasted their ability to offer 'the widest range of CNC lathes in Europe'. Customisation had provided apparent differentiation in the market place and their product technology was comparable with major competitors. Considerable progress had been made in the modular construction of lathes to offset the cost of customisation but many of the benefits were negated by their willingness to fit control systems from any one of four suppliers. This multiplied the cost of "interfacing" and servicing CNC machines. To avoid warranty problems, it was often necessary to source other components such as spindle motors and servo-drives from each controller supplier.

Even though TI claimed the largest domestic market share in CNC lathes, together with their machining centre and grinding machine businesses, they still could not match the throughput and sophistication found in the plants of Japanese competitors. TI could point to the installation of their own CNC machines, particularly at their Blaydon plant, and a demonstration area at Coventry; but they had foregone the opportunity for early in-house user experience in flexible manufacturing systems and damaged their credibility as suppliers of advanced automation.

When a new managing director was appointed in January 1985 to turn around the company, he made the scathing public statement that TI was 'organised for failure', saying that they had been using hammer and chisels on the shop floor while telling their customers that high technology is the only way to survive. Ironically, though the Blaydon plant had attracted the most investment over the years, it was closed in a further round of rationalisation in 1986 and production switched to Coventry where a major modernisation programme had been initiated.

In 1987, TI Machine Tools was the subject of a management buyout and became Matrix-Churchill (supported with Iraqi funds!), with the new board of directors declaring in the company newspaper that they were seeking ....'growth through international cooperation with other companies - possibly licensing deals, joint ventures or partnerships'. No such deals had materialised over the three years following buyout, though the new management had achieved fair success in the field of small flexible manufacturing systems (FMS) built around their CNC turning machines.

In addition to Matrix-Churchill, there are other manufacturers offering stand-alone CNC machines and cells, not the least of which is Yamazaki. By 1989, there was little indication that Yamazaki had decided to offer FMS's and speculation surrounding their deliberate strategy of being a follower. This is to some extent consistent with their approach elsewhere. Even though Yamazaki has accumulated substantial in-house FMS experience, they are not noted for going beyond supplying machining cells to external customers. Other manufacturers of CNC machines such as Dean Smith & Grace, BSA Tools and Beaver (a late entrant to turning technology) have adopted a cautious strategy; but unlike Yamazaki they are relatively small, have limited experience of in-house FMS and face a higher order of risk.

8.14 Milling Technology

In the high volume production of milling machines the UK situation is similar to that for centre lathes. One company, Bridgeport Machines, dominates production. It is Bridgeport's repositioning strategy to compete in the CNC machining centre segment, however, that provides an excellent illustration of what can be achieved over a five-year period.

The first stage in Bridgeport's revival was the introduction of an in-house designed range of vertical CNC machines in 1982 which allowed them to trade up on their existing customer base. The next stage involved a thorough search for potential licensors of machining centre technology, culminating in the signing of an inward licensing agreement with Yasuda of Japan to manufacture and sell a 300mm cube horizontal machine. In addition to giving Bridgeport reduced lead time in the market, the incoming know-how enabled them to speed up the design and development of two new vertical machining centre models in-house. Building on the success of the first licence agreement with Yasuda, a further agreement was signed in late 1986 covering the rights to a 450mm cube horizontal machining centre.

Bridgeport's strategy has been to carefully expand their product range from the lower end of the market where they have a position of relative strength. The market for each new model is thoroughly researched before approval and their policy is to produce only standard machines. A feature of their mixing of in-house and foreign sourcing of technology has been their willingness to continually improve on incoming product design and manufacturing know-how. In their modern plant, sets of prismatic machine parts are produced on machining centres using palletised loading on a 3-shift system (one minimally-manned). Bridgeport was one of only three machine tool manufacturers in the UK known to report pre-tax profits over the economic recession from 1980 onwards.

Bridgeport is currently competing successfully against Japanese manufacturers such as Yamazaki, Okuma and Makino, and provides one of the most visible shifts from late followership to aspiring leader.

Some machining centre manufacturers have sought to establish a presence in flexible manufacturing systems (FMS) and computer integrated manufacturing (CIM) systems. Many, however, have had to come to terms with the far-reaching policy implications of "sole responsibility" and concluded that the risk of going beyond machining cells and small FMS's is too great. An order for a single FMS could, in some cases, represent an unacceptable proportion of their annual turnover. For all but the largest SBUs, software is a major hurdle to be overcome.

The problem for machine tool manufacturers is that CIM has made the boundaries of the industry more difficult to define. Proficiency in software, either in-house or through collaboration, is already distinguishing those machine tool manufacturers who will remain in stand-alone machines from those who will participate in higher added value systems. KTM, for example, formerly part of the Vickers Group, has formed strategic alliances with Siemens to develop modular software for FMS and with the Hoskyns Group on CIM. Overall, however, the lead in systems "integration" is currently being taken by multinational computer manufacturers and management/engineering consultancies: partly reflecting the diminishing role of machine tool hardware in the total CIM package, and partly the need for manufacturing to be business-driven.

B.15 Grinding Technology

For many years, grinding technology has been labelled a "black art". This is mainly due to the complexity of the process brought about by continually changing wheel topography and the difficulty in controlling various machine parameters. These deficiencies meant that grinding failed to attract the attention of major CNC systems manufacturers and early developments were carried out in-house by machine tool manufacturers such as Jones & Shipman, Newall and TI. Most designs for control systems were crude, impossible to enhance and never got past the prototype stage. Later, these manufacturers switched to proprietary systems as they became available and this raised the prospect of greater compatibility with other metal cutting machines.

Current trends in grinding technology include:

(a) higher metal removal rates offer a feasible alternative to turning for primary machining operations;

(b) along with most machining processes, grinding machines are becoming increasingly multi-functional;

(c) machine features offer the benefits of continuous wheel dressing, in-process guaging, wheel breakage monitoring, vibration damping etc;

(d) automation, such as gantry loading and machine mounted robotic devices, has improved the efficiency of non-machining operations.

Grinding was held up as one of the most successful segments of the UK industry in the late 70's. Growth rates were twice that for all machine tools but sales were largely of the manual type and producers paid insufficient attention to the next generation of CNC. Indeed, the Science & Engineering Research Council spent £3m on grinding research in UK universities and polytechnics to remedy the situation. With the exception of turbine blade applications, few manufacturers were able to translate the benefits of the research, some of it misdirected, into sustained growth in CNC machines.

Inspection of the financial performance of grinding machine manufacturers in Table 34 shows that only the US-owned company, Landis Lund, claims the distinction of remaining in profit throughout the 1980's. In real terms its sales turnover has declined. Although Landis Lund offer a range of special purpose machines, its success lies mainly in a CNC cam-lobe grinder, a joint development with the Cranfield Unit for Precision Engineering. This has commanded a strong niche leadership position and greatly enhanced their credibility in grinding technology.

There are no other exemplars in the grinding field. Jones & Shipman, for example, the largest UK-based manufacturer of grinding machines, compete in the broad market for reciprocating and cylindrical machines. They have suffered in the same way as other machine tool manufacturers, unable it would seem to establish a defendable position as either a mainstream player or specialist nicher.

8.16 Metal Forming Technology

The metal forming segment encompasses a wide range of applications: from large hydraulic presses to sheet/coil processing equipment, press brakes and shears. As with grinding technology, metal forming machines were late to adopt CNC and when it came, it was smaller companies such as Cybelec and Hurco, who pioneered its use on press brakes - one of the few standard products in the fragmented metal forming segment. Metal forming cells and FMS are a relatively recent phenomenon, showing several years lag on metal cutting technologies.

The major global players in mainstream segments of metal forming equipment are the Japanese manufacturers Amada and Komatsu, and Trumpf in West Germany. Large US manufacturers seldom compete outside their domestic market. With the exception of Verson, UK manufacturers such as Edwards-Pearson, E W Bliss, Press & Shear and Joseph Rhodes are substantially smaller than their foreign competitors and compete in mature segments (eg press brakes, shears, punch presses, forging presses). They cannot hope to match the level of investments being made in the growth segments of laser cutting machines and handling equipment. Consequently, the performance of most UK manufacturers has been unspectacular.

The exemplar in metal forming technology in the UK is undoubtedly Verson International. Verson is one of the most internationally-orientated manufacturers in the industry and its dynamic chief executive has openly stated his ambition to become a world player.

The company's origins lie with the Verson Allsteeel Press Company in the USA which set up Verson International (VI) as its international sales organisation in the late 70's. VI acquired Wilkins & Mitchell, the UK power press manufacturer, from the receiver in 1982 and the HME coining press business from Cincinnati Milacron in 1984. When the US parent company ran into financial difficulties in 1985 (ie at the time of my visit), VI became the subject of a management buyout (with the equity participation of Citibank). Within a year, VI had negotiated a "reverse takeover" of Bronx Engineering, a UK quoted company specialising in metal processing equipment.

VI continued to expand through further acquisitions. In 1988, it purchased the intellectual property rights of Taylor Wilson (aluminium finishing), Bronx's long standing US licensor; and Daniel Smith (cold roll forming). By 1989, VI's sales turnover reached £40m and £10m had been invested throughout the group.

The successful strategy underlying VI's acquisitions programme is one of multiple niching. Ailing businesses were selected on their potential for group synergy and regeneration given access to an international sales network. This was explained by the Chief Executive as offering a range of related products to a common international customer base. A virtuous circle of ....'the more sales offices we have, the easier it is to increase turnover of our companies; and the more the turnover of our companies increases, the easier it is to support the opening of new sales offices'. VI's exports were running at 75-80 per cent of total sales by 1989.

Strong features of VI's regeneration of its acquired companies have been the paring down of 'non-essential overheads' (eg separate dining facilities, company cars and other management perks) and focus on managing the dynamics of change. Each business is said to be small enough for everyone to be on first name terms and the internal climate is conducive to teamwork. Nothing appoaching VI's attempt to manage strategic change was revealed in this research.

B.17 Automation and Special Purpose Equipment

B.171 An heterogeneous segment

The boundaries of the automation and special purpose machine segment are ill-defined. The segment includes a wide variety of metal cutting and handling equipment, such as rotary and in-line transfer machines, automated assembly equipment, robotic devices and numerous items of special purpose equipment. With the exception of industrial robots, production is characterised by one-off or low volume orders to customer's specification. The key success factors are listed under "customised machines" in Table 33.

B.172 Transfer lines and automated assembly equipment

The strategic problem facing manufacturers of transfer lines has been how to manage the rapid transition from "dedicated" to more flexible automation. Even though the signals of impending change were long visible in machining centres, the thinking of many executives was still locked into the kind of high volume operations required for engines transmission units etc in the motor industry. Few machining systems can approach the productivity of conventional transfer lines but user requirements changed and parallels may be drawn with the earlier example of multi-spindle lathes.

The trend towards flexibility has been assisted by developments on two fronts: (a) incorporation of programmable logic controllers and ac servodrives, and (b) "operator friendly" monitoring/diagnostic systems to locate the source and cause of breakdowns. The last development has also enabled manufacturers to reduce machine downtime.

Successful strategies in the 1980's have depended on the rate of adoption of these innovations, mainly originating outside the industry. Often the credibility of manufacturers has been at stake. Overall, however, there has been little to distinguish the technology strategies of individual manufacturers pursuing orders worldwide, such as Cross & Trecker, Joseph Lamb, Ingersoll, Hiller and Comau. Cursory examination of the orders won by these companies suggests that it is their commercial aggression and tenacity which has made them international players. This is not the case with UK-based manufacturers, who, apart from perhaps Cross International and Ex-Cell-O, have been more limited in their aspirations. Although manufacturers such as KTM, Marwin and Kingsbury have successfully commissioned various installations in the motor industry, they must be regarded as "second division" suppliers both in their outlook and international track record.

Activity in automated assembly equipment in the UK is extremely low by international standards. Assembly technology has experienced the same demands for flexibility as found in transfer lines. The future need will be to: (a) assemble families of parts with rapid changeover times, and (b) to incorporate vision and sensing systems. Electronics is the "lead user" industry for automated assembly, yet no UK-based manufacturer has had an impact on the fast-growing application area of surface mount technology.

8.173 Industrial robots

Tables 50-53 show the dominating position of Japan in terms of the number of robot installations. Despite the controversy surrounding the definition of a robot (ie as a "re-programmable" device in the UK), it is generally acknowledged that Japan accounts for about 60-65 per cent of the world installed base. In revenue terms, however, the largest manufacturer is Asea Brown Boveri with 17.4 per cent share of the $1400 m world market in 1988, followed by Yaskawa with 8.6 per cent and G M Fanuc with 7.0 per cent.

The two US pioneers in industrial robots, Unimation and Cincinnati Milacron, have had mixed fortunes and just managed to stay in the top dozen or so manufacturers. Their financial performance has never matched their technical excellence. Indeed, they were both victims of industry shakeout in the 1980's - Unimation was acquired by Westinghouse (USA) and later Staubli (Switzerland), and Cincinnati Milacron by Asea Brown Boveri (Sweden).

Unimation has a manufacturing operation at Telford and is the largest UK-based manufacturer. It is interesting to note in the context of this research that Unimation initially chose to exploit its technology in Europe in the mid 60's via a licence agreement with GKN Engineering and in Japan with Kawasaki. The agreement with GKN was terminated after only two years, at GKN's request. GKN was not committed to developing electro-hydraulics technology and inward technology transfer never got beyond the supply of fixtures and kit assembly. In contrast, the licence with Kawasaki flourished and they went on to claim almost 5 per cent of the world market in 1988.

Leaving aside Unimation, there are about 30 robot manufacturers in the UK, mainly pursuing narrow niche strategies. These include GEC Robot Systems, Fairy Automation and 600-Fanuc Robotic Systems. None has produced profits and it is doubtful whether they have the resources to sustain continuing presence in their chosen field. As shown in Table 52, UK-manufactured robots have been largely aimed at simpler tasks at the lower end of the price range, compared with Japanese robots in the middle range, and mainly Scandinavian robots in the higher price range. This is hardly a sufficient base on which to sustain a UK robotics industry.

B.2 INWARD TECHNOLOGY TRANSFER THROUGH LICENCE AGREEMENTS

B.21 Characteristics of Licensee Companies and Agreements

The analysis presented here covers 31 inward licence agreements in 22 strategic business units (SBUs), employing 7,780 people in 1984. The estimated total sales turnover of these SBUs amounted to £116m, of which about £28m (24%) may be attributed to the sale of licensed machines. It is expected that when several of the later agreements reach full production, the 24% will rise to 30-35% as these cover licensed manufacture or assembly of machines of relatively high unit price.

Table 24. Distribution of SBUs and Agreements by Annual Sales Turnover and Number of Employees in 1984

Sales Turnover £m	Number of SBUs	Number of Agreements	Employees	Number of SBUs	Number of Agreements
0.5	1	1	0-50	4	4
0.5-1.0	4	4	51-100	6	9
2.0-3.0	8	11	101-200	7	8
3.0-5.0	2	3	201-300	2	5
5.0-10.0	3	4	301-500	1	1
10.0-20.0	2	5	500+	2	4
20.0+	2	3			
	22	31		22	31

It can be seen from Table 24 that over half the agreements were concentrated in 12 SBUs having annual sales turnover below £3m. Further analysis revealed that 7 of these SBUs were privately owned companies, in which inward licensing was considered a useful way of making up for resource deficiencies without loss of independence. 4 of the remaining 5 SBUs in this relatively low sales turnover and employment category were divisions of much larger groups and at an early stage of licensing.

The changing structure of inward licensing is illustrated in Table 25.

Up to 1980, the USA accounted for 90-95 per cent of agreements but by

Table 25. Country of Origin of Licensed Technology

Country	Number of Agreements	(%)
USA	18	58
Japan	10	33
Europe	2	6
Other	1	3
	31	100

1984 this was reduced to 58 per cent, mainly due to the burst of licensing activity from Japanese manufacturers aimed at circumventing the "voluntary" restraint on imports. 7 of the 10 agreements with Japanese manufacturers investigated involved CNC machine tools and robots. It is not generally known that there were at least 3 agreements for other types of machine tool in existence between UK and Japanese manufacturers prior to 1981.

Table 26. Who Instigated the Licence?

Instigator	Number of Agreements	(%)
UK Licensee	19	61
Foreign Licensor	4	13
Mutual Approach	1	3
Other Third Party	3	10
Not Identified	4	13
	31	100

Table 26 shows that in 19 (61%) of the 31 agreements the UK licensee was the party making the first approach, suggesting an element of "opportunism" underlying the statistics. Where possible, this was cross-checked with other executives in both licensor and licensee companies. It should be noted that at the time of the first round interviews, the Heads of SBU associated with 21 (68%) licence agreements had also been involved in the negotiation of the original agreement. In only 4 cases was it not possible to ascertain which party initiated the approach due to longevity of the agreement and many staff changes.

The unique position of 5 SBUs as the prior distributor of the licensor's machines effectively gave them "sitting tenant" status, requiring conversion of the distributorship to a sales/manufacturing licence. At this point in the relationship, the market for the machines had been established and both parties knew enough of each other's capabilities and aspirations to set the licensing arrangement on a firm footing.

Only one SBU, a division of a large diversified UK group, overtly operated a "trap search" or "trawl" for a licensor, whereby they let it be known that they were seeking certain technology and awaited approaches from foreign licensors. The SBU claimed to have carried this out successfully in other areas of their business and it is suspected that a similar mechanism may have attracted potential licensors to at least two other SBUs once their intentions had been signalled to the market.

The four main reasons cited by the Heads of SBUs for them entering into licence agreements with foreign manufacturers are listed in Table 27. This data was extracted from replies to open-ended questions in the interviews in preference to requesting ranking according to a predetermined set. This maintained continuity of discussion and avoided exposing respondents to alternatives that they might not have otherwise considered. Further, by allowing them to

Table 27. Main Reasons Cited for Inward Licensing

Reason	Frequency of Occurrence Number of Agreements	(%)
To acquire complementary products quickly (ie buying lead time):	26	84
UK licensee did not possess the resources to design and develop the machines at the time:	23	74
Response to an opportunity not to be missed:	15	48
To achieve progression towards flexible manufacturing system:	7	23

articulate their motivations for licensing in their own way, an attempt had been made to minimise the probability of normative replies and prompting replies to later questions.

In the 84 per cent of agreements in which complementary product technology was cited as a reason for inward licensing, executives expressed this as extending or filling gaps in their product range by 'buying lead time'. The licensing option was attractive to manufacturers faced with the recurring problem of defining priorities under conditions of stretched resources. Many respondents said that licensing had allowed them breathing space to catch up in an existing technology or diversify into a related area quickly. They fully recognised the difficulty of keeping abreast of competitive developments on all technological fronts. Licensing was found to be an acceptable "follower" strategy for introducing proven models with low cost and risk.

The second most common stimulus to inward licensing, underlying 74 per cent of agreements, represented a complex combination of skills shortages, lack of training and the heavy emphasis on product technology in some SBUs. Implicit in the decision to take a licence was the assumption that incoming know-how could be assimilated. No attempt was made to examine the detailed change in skills profile of technical staff in licensee companies over say a five year period, but it was observed that while staffing levels had reduced in all areas of the company, there was evidence of recruitment of electronics, software and applications specialists appropriate to future requirements of the licence. The serious shortfall appeared to lie in updating manufacturing and production engineering skills, though this was seldom mentioned by executives and it was widely assumed by them that almost any machine could be manufactured with acceptable quality and efficiency.

Of the 15 (48%) agreements classified as "response to an opportunity", 8 were related to the pending termination of an existing licence held by a competitor in the UK. These were easy to verify and typically involved the UK holder withdrawing from the business or falling into receivership, or one party not wishing to renew the agreement beyond its original duration. 6 of the 8 agreements transferred to another UK manufacturer resulted from approaches initiated by the new licensee and one by the licensor. The instigator of the remaining one was not satisfactorily determined.

When a licence agreement changes hands, the prospective new UK licensee may seek to employ one or more key staff from the previous licensee, thereby smoothing the transition and simultaneously strengthening the new licensee's negotiating position. When Vaughan Associates, for example, fell into receivership in 1982, their US Bodine licence for automated assembly equipment was acquired by Bridgeport Textron along with the product team and a number of partially completed orders.

The other 7 agreements loosely falling in the "opportunistic" classification emerged from intelligence gathered from networks of personal contacts, leads followed up after an overseas visit or 'by accident'. Early access to information about the future availability of licences and speed of reaction were perceived to be important dimensions of competitive advantage. Moreover, the decision processes associated with these agreements were characterised by participation of only a few executives over a highly compressed time scale. Special research programmes were rarely initiated to assess the fertility of markets and the relative merits of the licensor vis a vis competitors. Choice was restricted to a go/no-go decision on the single licensor under consideration based on what was known collectively at the time. There was a strong feeling among these executives that if they had not moved quickly to secure the licence, then a competitor would certainly have done so.

Table 28 examines the timing of progression to various levels of in-house manufacture associated with the 17 agreements signed after 1980. This data quantifies the "lead time" perceived to be important by executives in UK licensee companies, showing substantial dispersion about the mean due to varying levels of technological complexity.

Estimates by executives of how long it would have taken their company to

Table 28. Time Scales for the Inward Transfer of Technology

Stage in the Transfer Process	Mean Time (months)	
Estimated time period from the decision to go ahead in the product area to actually signing the licence agreement:	11.7 (SD=7.4)	N=9*
Time period from signing the licence agreement to first sale of the machine:		
(a) for machines initially imported from the licensor*:	6.6 (SD=5.2)	N=9*
(b) for machines assembled from kits supplied by the licensor:	13.4 (SD=11.0)	N=7**
(c) for machines manufactured in the UK (over 70 per cent by value):	17.7 (SD=10.5)	N=14

Note: * excludes five UK licensees who were already importing machines before entering into the agreement.
** includes two joint ventures

commercialise an equivalent machine of in-house design yielded little in the way of usable data. Feasibility studies were notably absent from the decision-making process in about 50-60 per cent of cases and most executives said that design would never have been attempted from scratch. Those 9 executives who, in hindsight, were prepared to give their best estimate, indicated that times from product concept to achieving full manufacture and commercialisation were reduced by 2 to 3.5:1 through inward licensing. Some individual comments on lead time and economies of scale in design and development were revealing:

> 'We thought that we could have done the job in the same time frame as our licensor but they were over two years ahead ....It turned out that we would have been too optimistic in time and cost.' Developing software and setting up manufacturing operations were highlighted as main sources of variance. The technology was in the very early growth stage.

> 'The sheer scale of design and development precluded our starting from scratch and we were too late anyway. We would never have recouped the investment and have starved our other projects.' At the time of signing, the licence provided related diversification.

> The technology was in the early maturity stage but capable of enhancement.
>
> 'My engineering and production directors said they could come up with the goods: they probably could have done ....eventually! The risk of introducing new machines of our own design is too frightening to contemplate. The licence has bought us valuable lead time.'

B.22 Scope of Licence Agreements

B.221 The licence document as a point of reference

The scope of a licence agreement defines the techno-commercial boundaries of the manufacturing and selling right granted by the licensor to the licensee. Leaving aside the technological content for more detailed analysis later, the three major components of "scope" are: (a) the definition of products and their field of use, (b) duration of the licence, and (c) degree of exclusivity. These relatively short statements require careful thought at the outset because they establish certain commitments from both parties over the life of the agreement.

If it can be assumed that the licence document is the point of reference for what was agreed at the time of signing, then it must be concluded from this research study that the scope of licences was loosely defined and subject to considerable drift. Often, verbal descriptions from executives bore little resemblence to the wording in the original agreement, although it could be implied from subsequent correspondence and actions that the scope had changed. This partly reflected the need to build-in flexibility and partly the difficulties encountered in assessing the future impact of particular technologies and the way product/market segments might develop. While the general direction may be forecast with some certainty; at the level of individual machine design and application, there are problems surrounding the timing of technological innovations by machine tool component suppliers, manufacturers and users.

B.222 Definition of the licensed products

Machine tool licence agreements normally relate the technology to particular machines and the trend has been to name in the agreement individual models or use the generic term covering a range of models. A common way of delineating the licensed product(s) found in the agreements studied was by size of workpiece handled by the machine; such as the "swing" of a lathe, sheet width of a plate forming machine, payload of a robot etc. Other classifications involved the use of machine configurations (eg vertical, horizontal, radial), drive mechanisms (eg mechanical, hydraulic, electrical), sophistication of control technology or some combination of these. No restrictions on field of use were found (ie exclusions for particular applications, customers, industries), largely because in machine tools they would be impossible for the licensor to police and there would be no point in retarding applications development.

It was not unusual to find a broad range of machines being offered, covering new and mature designs and both standard models and specials. Only in exceptional cases had licensees, faced with such variety carried out a market survey for each model. This would have helped them during negotiation to decide whether to accept a "blanket" royalty rate on all models, to seek a reduced rate for mature models or have some models deleted from the package. Alternatively, the UK licensee might have considered acting as an agent for some models of low or doubtful volume, possibly with an option to build under licence at a later date if the volume should justify it. The kind of predicament that can arise through overlooking this aspect of licensing strategy is best illustrated by reference to an example where the interpretation of product scope and the spirit of a licence agreement were questioned.

A small UK company had successfully imported certain machines from the USA for several years and had been pleased to manufacture them under licence in the smaller sizes. Up until that time, sales of smaller machines had by far exceeded those of the larger machines, and it was agreed that the latter would continue to be imported. Relationships between licensor and licensee staff were said to be excellent. Later, the balance of orders (by value) switched to the larger machines and the licensee repeatedly requested extention of the scope of the agreement to accommodate the change. The US licensor wished to retain manufacture of the larger machines to preserve volume production but by 1979/80, also to take advantage of the low dollar/sterling ratio.

By 1984 the currency advantage had reversed and the licensor was more amenable to extending the range but insisted on a higher royalty rate for the larger machines. The UK licensee felt "locked-in" to the situation and following a bitter round of meetings, reluctantly accepted the higher rate. Neither party wanted a break nor any damage to the external reputation that might result from open conflict. An executive in the US licensor company described the new arrangement as justified because it involved a 'solution to a new set of problems, requiring a "step" increase in know-how in-line with the scale-up to the larger size'. Managers in the UK licensee company felt that they were the victim of powerful licensor.

The foregoing example is by no means unique. Close examination of agreements which restrict the range of machines manufactured under licence by some arbitrary split in size or capacity showed areas of potential conflict seldom anticipated at the signing date. Licensors and licensees were generally able to cope with single orders outside the range of machines manufactured under licence but the sourcing problem became more acute during recession and several clashes were discovered as both licensor and licensee found themselves bidding for the same orders in third markets.

B.223 Duration of licence agreements

The rationality for arriving at a particular duration for licence agreements and extension periods was not obvious. Some executives had perceptions of what was "normal" or "correct" for machine tools within the limits of their own experience. Others were guided by their corporate lawyers and industrial property specialists. And yet others accepted what was pencilled-in to the agreement drafted by the licensor. Most seemed to think along the lines of 5 years as short term for original agreements and 10 years as long term. Table 29 shows that 30 per cent and 49 per cent of agreements fell into these respective time periods.

According to the literature, licensors tend to favour a shorter term of years than sought by licensees, because the former have more to lose if the transaction does not work out well and they do not wish to be committed for a lengthy period to an, as yet, untried licensee. Such caution on the part of licensors is not unreasonable, nor was it absent from the present study. As a generalisation in machine tool licensing, it may have been more applicable to the 1950's and 60's when the lower sophistication of machine design facilitated an easier transfer over a

Table 29. Licence Duration, Extension and Proximity to Expiry Date

	Number of Agreements	(%)
Original Duration of Agreement:		
3 years	2	6
5 years	9	30
6-9 years	2	6
10 years	15	49
15 years	1	3
20 years	1	3
Indefinite	1	3
Agreements within 1 year of expiry date:	10	32
Agreements within 2 years of expiry date:	15	49
Extended beyond original duration:		
on a year to year basis	2	6
by 5 years	1	3
by 10 years	4	12
by 20 years	1	3

shorter period. As shown in Table 28, the complex product and manufacturing know-how of the 1980's has taken up to 3 years to transfer in some cases, making 10 years duration a practicable proposition for both parties. Licensees are then able to build up production levels and reap economies of scale and experience. In return, licensors accumulate royalties long before expiry of the agreement.

Agreements of shorter duration may only span one business cycle and their success may be more dependent on timing considerations and the frequency of orders than on technological complexity. Most of the 9 UK licensee companies accepting agreements of 5 years duration were well known to the licensor and their capability to build and sell particular machines not in doubt. The machines were mainly of either the metal forming or special purpose type, perhaps only attracting a handful of orders over the 5 year period. Invariably these machines were originally licensed to enable the UK manufacturers to supply complete packages as part of much larger capital equipment projects. When executives were asked if the duration stated in the agreement was shorter than they would have liked, they seemed unconcerned, giving answers such as ....'it was about right' and '....duration was not a major issue'.

B.224 Exclusivity and territorial restrictions

The allocation of territories on an exclusive basis is one of the most controversial commercial restraints in licensing. The problem lies in the inherent conflict between the legitimate exploitation of intellectual property rights intended to give their owner a protected and privileged position, and their use to restrain trade unreasonably. Since the UK is a member of the EEC and most licensors in machine tools are US companies, then any contractual arrangements must be examined against a background of competition and law in Europe and North America.

Table 30. Exclusive Sales Territories Named in Inward Licensing Agreements

Territories	Number of Agreements
UK or UK/Eire only	12
EEC (inc. UK) only	7
EEC and other Western Europe	10
Old/Existing Commonwealth	7
World	2

The position with regard to exclusive territorial restrictions in UK licence agreements is shown in Table 30. It can be seen that exclusivity in sales was generally restricted to either the UK or extended to the whole of the EEC and other Western European countries.

The most striking feature when examining these territories was the pattern discerned in the granting of exclusivity and non-exclusivity, depending on whether the foreign licensor was a US or Japanese company and the extent of their licensee network worldwide. This showed clearly the "triangular" technology trading situation emerging in the 1980's, with the main inflow to Europe coming from the USA and to a lesser, but growing, extent from Japan. Not surprisingly, licensors would not allow access to their home market, except under special circumstances of "buy back". US licensors tended to retain Canada, Central America (inc. Mexico) and Japan for themselves. Japanese licensors retained the USA and certain Far Eastern countries for their own exploitation. Nine (29%) licensor companies had licensing operations for identical products in more than one country. Five of these were US companies which had licensees in both the UK and Japan.

Seventeen (55%) agreements named non-exclusive sales territories in addition to those exclusive territories listed in Table 30. US licensors appeared more liberal in granting non-exclusive territories than Japanese licensors, though this may relfect the relatively recent entry of Japanese manufacturers into outward licensing and the stage reached in developing their network compared with US manufacturers. Of particular interest in this respect was the treatment of territories such as the Soviet Union, itself a net importer of technology, and the Eastern Bloc Comecon countries which are large consumers of machine tools. US licensors were generally of two persuasions. On the one hand, some US executives were fiercely nationalistic and did not wish to see machines using their technology destined for Comecon countries and they morally supported the NATO CoCom embargo. On the other hand, there was a willingness to let licensees exploit their geographical proximity without interference. In contrast, Japanese licensors preferred to retain Comecon countries and were adopting a more cautious line on other trading blocs. A particular case in point was the advantage seen by US companies in allowing their UK licensees to exploit Commonwealth links. Export orientated Japanese manufacturers have regarded this route as of diminishing importance and have tended to set up their own sales offices or agencies.

8.23 Patents

Patents in machine tool technology were found to cover complete machine configurations or specific devices such as toolchangers, spindle assemblies, grippers etc. Instances of manufacturers allegedly copying and, therefore, infringing patented technology were often cited by executives but it was revealed that cases had normally been settled without litigation, either by the infringing party withdrawing from the product area or taking a patent licence. These seemed to have a localised impact on certain companies and in particular sub-segments of machine tool technology. Their precise nature was difficult to determine. It was considered sufficient here to note that in cases where infringement did not reach the courts, there lingered considerable uncertainty about whether competitors would acquiesce in their pursuance of their patent rights and the extent of real or imaginary threats of litigation. Questions of validity and infringement of patents may be covered adquately in licence agreements but these were seldom found to relieve anxiety.

Data on the incidence of one or more patents in the technology package in Table 16 revealed that 21 (68%) agreements included active patents at the time of signing. The salient pattern to emerge from interviews with executives was the general lack of knowledge on the patent situation concerning their inward licence agreements. At least two thirds of respondents had to refer to the agreement to ascertain whether patents were included and if so, whether these were still active. In several cases patents had expired and the licences, which were originally combined patent, trade mark, design and know-how licences; had reverted to licences covering the last three. On a cross-sectional basis for the period 1984, it would be fair to estimte that the 21 (68%) agreements in which patents were a feature on signing had reduced to 16 (52%).

Most agreements merely mentioned patents in passing, using such wording as: ....'all patents and other intellectual property related to the reference products'. This vague description was not regarded as important by executives, though a number said that having been asked questions about patents they would seek clarification. Of the six executives followed up by the author on this issue, one agreement was discovered to contain two patents stated as "pending" at the time of signing six years earlier but had not been granted. The executive said that he would not pursue the matter further with his licensor as patents were not a major consideration. The remaining 5 executives had not reassessed the patent situation in their agreements over a three month period subsequent to being interviewed.

A schedule of patents was known to be provided with the agreement in only 8 cases. Of these, 4 were in SBUs of large groups which had their own corporate patent section. Respondents in these companies gave the impression of being well informed about the strength of their licensor's patent position and valued professional corporate assistance both prior to signing the agreement and subsequently in monitoring patent developments. A further 6 SBUs had used the services of independent patent agents when assessing the technology on offer but there was a marked propensity to follow the same approach found in US licensor companies of 'leaving the legal aspects to the lawyers'.

It is impossible to say whether the patents included in long standing agreements were rigorously assessed by prospective licensees during the period of negotiation. Agreements were largely drafted by the licensor on their terms and the weight of evidence points to patents appearing in technology packages more for the licensor's added protection from patent law and exemptions from aspects of competition law than for their contribution to "core" technology. Such competitive advantage from patents as existed in ageing agreements in 1984 was relatively weak and infringement by competitors had passed unnoticed and/or unchallenged.

B.24 Trade Marks

Manufacturer's names and trade marks have always played an important role in the marketing of machine tools. It is, therefore, not surprising to find them appearing as a key element in technology packages as licensors seek exposure of their marks worldwide and licensees wish to share in the "goodwill" and standards of quality they confer. Table 16 shows that 15 agreements covered use of the licensor's mark and 12 involved joint names.

Long established foreign manufacturers offering licences for machines with no close competitors were in a strong position to impose their own conditions. At least 6 licensors were known to have made clear their desire to include trade marks in the package at an early stage of negotiation. A statement of their use in promotional material, together with the wording and size on the machine nameplate, was also a feature of such agreements. This did not appear to be a point of contention.

It is not known how many negotiations were terminated on the issue of trade marks. Even allowing for post-rationalisation on the part of executives faced with preconditions, UK licensees were more than willing to be associated with prestige trade marks. Several executives felt that acquiring certain licences for their company was a major coup and they openly admitted that use of the mark had enhanced their standing amongst customers, gained entrée to export contracts and often provided spillover to other product/market segments not covered by the licence. Positive attempts had been made by these manufacturers to re-position themselves.

A similar situation was discovered with joint use of licensor and licensee marks. There was some evidence of licensors opening negotiation by taking a rigid stance on the use of their marks but they seemed to have readily compromised on the form of a joint mark. This is commonly found in agency agreements for imported machines and recognises the contribution from both parties. According to EEC law, the licensor may impose his mark so long as the licensee can also put his name on the machine. Additionally, there is a minor commercial advantage to be gained from the company whose name appears first as it is this which dictates their location in trade directories. 9 of the 11 joint marks had the UK licensee's name first.

Only 4 licensees were using their own trade mark on machines manufactured and sold under licence. These were all divisions of large engineering groups and expressed interest in maintaining a consistent product and corporate identity.

Overall, UK licensees had only moderate appreciation of the use of trade marks and very little thought had been given to evaluating their contribution to the package and the long term implications. When asked about the trade-offs, such as possible reductions in royalty rate likely to arise from the three situations of licensor's mark, joint mark and own mark; it was clear that financial considerations were not to the fore. As will be discussed later, the presence or absence of the licensor's name or mark becomes and important issue when the agreement expires or is terminated. Unlike patents and other forms of industrial/intellectual property, trade marks have an indefinite life theoretically.

B.25 Designs and Copyright

The written-up part of the technology transferred to licensees normally involves engineering drawings, schematics, manuals, specifications, product literature, software etc. These items are an essential part of the communications process and the foreign licensor can protect them against unauthorised reproduction at minimal cost simply by claiming copyright. For designs which are novel but lack the inventive step necessary for the granting of a patent, the licensor may seek monopoly rights by formal registration with the Patent Office. Alternatively, designs which do not meet the criteria for registration may be afforded a measure of protection under the peculiarly British concept of design copyright.

The incidence of registered designs in this study was minimal. The US system of "design patents", which is roughly equivalent to the UK system of registered designs, was used to probe the attitudes of executives in US licensor companies towards registering designs as a possible intermediate level of protection between that of patents and copyright. Compared with patents, there was virtually no enthusiasm for registering designs in the UK as a pre-requisite to licensing and the significance of design copyright had not been understood. A typical reply from US executives was that they ....'left those sort of questions for their lawyer to answer'.

Engineering drawings comprised the bulk of the documentation and these were supplied mainly in the form of blue prints or microfilm. Since drawings are a highly "visible" component of the technology package and the first to be disseminated within the licensee company, their psychological impact on expectations was found to be critical. Engineers in licensee companies recalled that the first batches of drawings were eagerly awaited and qualitative judgements on the value of the technology were quickly formed from them.

Redraughting of the licensor's drawings was fairly common in UK licensee companies: to "Anglicise" or "Europeanise" them; to recode parts schedules to accommodate local suppliers; and in some cases, to convert the format to house style. Licensees, less concerned with perfection in draughtsmanship, scribbled notes on blue prints in the early stages but it was observed that eventually, a large proportion of production drawings were redraughted. Engineers and design office staff in UK companies in which licensing was a way of life, seemed to take such matters in their stride; as did those well experienced in working with other manufacturers and sub-contractors. Newcomers to licensing generally underestimated the cost and effort required to tailor designs to their own procedures and market requirements.

The high standards set by UK companies in the presentation of engineering drawings and their use as the main medium for communication alongside product know-how, frequently provided the focus of attention during discussions with staff at all levels. While documentation from licensors for external use (eg sales literature, training manuals) was felt to be acceptable with only minor changes, the quality of drawings for internal consumption was singled out for criticism. Many US licensors, for example, seemed to have merely bundled drawings together for transferring to their UK licensees. The quality of some drawings, particularly in detail design, was judged to be so poor that redraughting was necessary before they could be passed over to the production department or sub-contractors. Similar problems were discovered with other foreign licensors but since they were fewer in number than US licensors, generalisations become more difficult. All that can be said is that the resolution of conflict between US licensors and UK licensees with regard to designs was greatly facilitated by common language and cultural values. Several senior executives, having experience of both US and Japanese licensing and agency arrangements, felt that the importance of language showed itself mainly in day to day problem-solving situations. Whereas a US licensor might be consulted immediately by telephone or telefax, a Japanese licensor might not be contacted at all and the solution sought within the licensee's own engineering department.

Cultural factors affecting approaches to design by Japanese licensors emerged from discussions with electronics and software engineers, though these would require further investigation to ascertain their wider occurrence. One Head of SBU licensing-in Japanese technology spoke of the 'illogicality' of electronics circuitry and software design' and the problems this introduced for fault-finding and future enhancement. Another referred to the controller on his licensed machine tool as 'functionally reliable with an aesthetically pleasing facia panel but crude and not too logical at the back.' The last view was shared by other engineers in the SBU who also added observations on flimsy design and 'engineering down to a specification, and no more'. Such comments correlate with more widespread opinions among non-licensees concerning 'lack of ruggedness' and 'built-in obsolescence' of Japanese machine tools and robots. Perceptions related to the illogicality of designs may be rooted in the education and training of designers in Japan compared with Europe and North America. At no time during this study was criticism to be heard of the reliability and performance of machines in service.

B.26 Know-how

Heads of SBUs identified know-how as a vital element in 28 of the 31 agreements. In roughly three quarters of these, know-how was felt to be of greater importance than patents. In the remaining 3 agreements, know-how may be classified as "ancillary" to the patent licence (ie just sufficient to allow the patent(s) to be worked). With few exceptions, the efficient transfer of know-how during the start-up period was claimed to be more critical than ongoing know-how in later years.

It was found that during the first 2-3 years, transfers of machine tool technology were "licensor-led", followed by a tapering off in the flow of know-how as licensees gained confidence and licensors adopted a "responsive" role. the main mechanism for the transfer of know-how during start-up was the training of licensee staff and the progression from imported machines to kit assembly and full manufacture. Engineers spent a few weeks at the licensor's plant learning procedures and participating in all stages leading to the commissioning of a finished machine or preparing a kit for export to the UK. This was invariably followed by engineers and others from the licensor company assisting the licensee to produce the first few machines during the transition from kits to full manufacture.

The costs incurred by the licensor and licensee during start-up depended on the complexity of the licensed products and their manufacture. Most agreements specified the costs to be borne by the licensor - normally expressed as a maximum number of man days for staff of a given level, with some accompanying statement regarding obligations to pay for travelling expenses and accommodation. The number of man days spent at each location varied from a few days in the case of transfers of essentially product technology, to several months where there was extensive reorganisation and updating of manufacturing facilities. Beyond the agreed periods for training and commissioning, any additional costs were the responsibility of the licensee. In practice, licensors were found to absorb or share costs incurred in response to reasonable requests for assistance.

In UK companies which had recently entered into licensing agreements, the likely impact of know-how on the company's fortunes was a major talking point. Announcements had received a fair amount of publicity in the technical press and it was interesting to observe how executive's elation and enthusiasm was often tinged with post-licensing anxiety as they attempted to rationalise the decision and reduce dissonance. Such worries as surfaced at the interviews were largely related to whether the licence represented merely another machine added to the range, a minor switch of direction or more central input to the company's survival strategy. Executives with prior experience of international licensing operations in machine tools or other engineering products, appeared better able to cope with the intangibility of know-how, although some perceived their personal credibility to be at stake in the event of the licensed know-how not turning out to be what was purportedly on offer. Some found comfort in observing that their UK competitors had licensed-in similar know-how.

Licensees of Japanese manufacturers faced greater external pressure and press scrutiny than other licensees during the early 1980's. The alleged reluctance of export-orientated Japanese machine tool and robot manufacturers to progress beyond the assembly of imported kits and questions about the transferability of Japanese know-how were recurring themes. By 1988, only one licensee, Bridgeport Machines, had moved swiftly towards full manufacture of Yasuda horizontal machining centres to prove the critics wrong. At least three others had successfully assembled kits but the prolonged recession had caused sales projections to be revised downwards and target dates for part/full manufacture to be postponed.

Inward licensing had created quite disparate demands for know-how in UK companies depending on their previous experience in machine tool manufacture and the maturity of the technology. The following examples illustrate how contextual factors dictated the know-how content:

(a) Several UK licensees were using know-how to quickly update their product range and manufacturing operations by a whole generation of sophistication. An obvious example was the shift from manual to computer numerical control. This brought with it the need for electronics and software know-how, together with markedly higher standards of precision. Although CNC units were typically bought-in as a proprietary item, the licensor's know-how in interfacing with the machine was important and there were other control requirements to be met such as routines for diagnostics, tool condition monitoring and touch-trigger probing.

Demands for improved positional accuracy and repeatability manifested themselves in finer dimensional tolerances and better surface finish on machined components, incorporation of recirculating ball-screws, spindle bearings with thermal control, low friction/wear way slides, substitution of electric motors for gears and hydraulics etc. Similarly, more rigorous assembly procedures were introduced forcing licensees to use techniques such as laser alignment and the sub-assembly of key items in "clean" rooms. These changes required the transfer of substantial product and production engineering know-how and were often accompanied by much-needed investment in new equipment.

(b) Some UK manufacturers, long established in customised machines, had licensed-in know-how for standard machines hoping for longer production runs and possibly flow-line assembly. The reverse situation was also common, as manufacturers strived to achieve what they believed was a better balanced product mix and cash flow situation. Licensees following the former route to diversification had recruited and retrained staff to absorb the incoming know-how, especially in the manufacturing/production function. It is important to note that by the time technological know-how associated with standard machines is available for licensing, it is usually entering the mid-growth phase of its life cycle and semi-codified. Thus a continuing flow of know-how was important to ensure that cost-reducing benefits emerging from subsequent re-design and value analysis by the licensor were translated quickly into price competitiveness by the licensee.

(c) Licensees wishing to position themselves close to the frontier of a fast-moving technology (eg robotics applications) frequently licensed-in know-how almost as it unfolded and long before patents were granted. This presented special problems because the know-how was so dynamic and fragmented that by the time it was codified, it was either in the public domain or approaching obsolescence. One UK licensee in this position relied heavily on the verbal passing-on of know-how and claimed to have two or three staff in the licensor's plant and development laboratories at any point in time. The agreement was interesting because it had to accommodate the quite different organisational styles of foreign licensor and UK licensee. The licensor was said to be ....'entrepreneurial, creative and exhibiting some difficulty in recognising that they had moved into the production phase'. In contrast, the UK licensee, a new entrant, had strengths in electronic systems know-how and extensive experience of implementing business planning and project control procedures. This was believed to have led to good commercial and technological fit.

(d) Small independent UK companies operating in particular market niches had sought technological progress through licensing on a more modest scale than in the previous three cases. One licensee, for example, wished to move from a product range totally dependent on mechanical design to encompass electro-hydraulic systems. The primary objective was to license-in complementary products which not only embodied the licensor's proprietary know-how but also obviated the need to employ an hydraulics specialist in-house.

UK licensee companies which had passed the half-way stage in their agreements were in a better position to judge the value of know-how and staff were generally willing to share their experiences. It should be pointed out, however, that there was considerable variation in perceptions found at different levels within and across functions. Heads of SBU were remarkably consistent in the generality of their replies. There was evidence of most of them treating inward licensing as a project during start-up and of positive attempts to prepare budgets and compile schedules. While cost and time over-runs were admitted in a few cases, it was difficult to get behind the "public face" response that the inflow of know-how had been well managed and assimilated with minimal disruption. Cross-checks with lower level staff often revealed that claims of having absorbed know-how "within budget" often disguised the fact that projects were under-resourced and there were hidden adoption and dislocation costs which passed unrecorded.

Under-resourcing was a symptom of a wider problem in UK machine tool manufacturers, in that tight constraints in all functional areas had led to the deployment of people and cash to licensing constituting little more than would normally be allocated to an agency agreement. Comments from directors, managers and engineers on the resourcing problem were rooted in what they saw as the erosion of staff numbers in product engineering and manufacturing/production, resulting in "fire-fighting" and diluted effort across all fronts. Many engineers mentioned that the build-up of work associated with the inward licensing project was uneven; they were required to switch tasks at short notice and to fit work into an already demanding day. Further probing revealed that this was partly due to the rigid functional organisation structure commonly found in UK machine tool companies. While about one third of licensing projects could be said to have been handled flexibly by small teams and task forces, the absence of a colleague from the department on temporary secondment to the project or on training with the licensor had caused other work to suffer, with little or no understanding from top management.

The gradual thinning of human resources had not escaped the eye of US licensors, for they too were facing similar problems. Some executives were clearly worried that at a time of growing technological change and complexity, UK licensees were increasing their dependency on incoming know-how and effectively shifting costs back on the licensor. The impression was gained that the continuing employment of certain key people in the UK licensee company would be a major determinant in future re-negotiation or possible termination on expiry of the agreement. These people were typically middle managers and senior engineers well versed in the licensor's systems and appeared to act as "gatekeepers" for dissemination of the licensor's know-how.

A critical aspect of know-how examined in the unpackaging process concerned the continuing flow over the life of the agreement. The existence of clauses requiring the two-way exchange of improvements in know-how was identified in 25 of the 28 agreements in which know-how was a main feature. At least 6 of the older agreements contained wording that amounted to a "grant back" situation (ie that all patents and improvements by the licensee should automatically be assigned to the licensor). Such one-sided agreements reflect the relative bargaining power of licensor and licensee at the time and would be unlikely to survive challenge under UK, EEC and US competition law unless changed to a mutual and non-exclusive sharing agreement.

A two-way flow of improvements in know-how was welcomed by UK licensees. Evidence in the form of actual examples suggested that these were minor or incremental in nature and mainly flowed from licensor to licensee. Some innovations originated within the foreign licensor company and others could be traced to inputs from their component suppliers, the know-how finding its way to the UK licensee by virtue of early use by the licensor. This gave certain UK licensees a head start over their competitors and it would be reasonable to suggest that adoptions would have been much delayed or ignored without "licensor pull". Electronics design and applications engineering accounted for most of the improvements in know-how, with the latter relying heavily on informal channels of communication.

The transfer of know-how followed this pattern up to the mid-1970's when the advent of microprocessor control systems began to threaten the product competitiveness of both parties. Machines that were envisaged as "manual" at the commencement of agreements had programmable logic controllers or full CNC applied to them in the early 1980's. This technological leap forward severely tested some licensing relationships as foreign licensors and UK licensees consulted their agreements to ascertain the original scope of models offered under licence, the status of derivatives and what had been said about the exchange of know-how. A wide variety of responses were identified from UK licensees ranging from: (a) do nothing and let the agreement run its natural course, (b) set up a parallel in-house development project, (c) propose a joint development project, and (d) let the licensor update his know-how accordingly on the premise that he had a contractual obligation to the licensee.

It was encouraging to discover 6 cases where the UK licensee had approached a more equal partnership with the foreign licensor and this had resulted in joint development programmes. It is likely that each partner would have proceeded alone if the other had not been interested in collaboration. But there were tangible benefits to be had through shared costs, reduced royalties and the future prospect of joint ventures or cross-licensing arrangements. The partners had also noted a boost to personal relationships. These positive attitudes to the dynamics of technological change contrast markedly with the precarious strategy of UK licensees who shifted the responsibility for progress on to the licensor. This was detected as a factor underlying at least 7 agreements and at its most sensitive in one particular case where the foreign licensor was reluctant to pass on state-of-the-art know-how in CNC because the updated machine was 'still in the experimental phase'. Executives in the licensor company were silent on whether they considered the advance fell within the scope of the licence agreement, which was within 2 years of expiry. They were clearly retaining know-how as a bargaining ploy. Also at stake, and of considerable importance to the UK licensee, was the potential for machine refurbishing business and the retrofitting of CNC.

And finally, a controversial clause concerning know-how in many old agreements, deleted in subsequent re-negotiations or totally absent from recent agreements, was that which formally tied-in the licensee to purchasing certain components, intermediate assemblies, materials and equipment from the licensor or a nominated supplier. "Tying-in" provisions are normally regarded as anti-competitive because licensors can utilise them to increase exports at inflated transfer prices and as an indirect control over licensees. In practice, they exist on an extra-contractual basis because they represent "embodied know-how" and ease the transfer process, especially during start-up. This does not put them beyond the reach of the law. Most participants argued justification on grounds of technical necessity for exploitation of the invention, attaining minimum quality standards and the existence of reasonable alternatives.

Excluding the UK licensees importing kits during 1984, there were 7 agreements in which complex components (eg leadscrews, spindles, intricate castings, gears) were being imported from the licensor. In each case it was considered by both parties as uneconomic for the licensee or sub-contractors to invest in tooling and other special facilities to accommodate low volumes.

On the face of it, 8 agreements were discovered to involve importation of the same proprietary components (eg controllers, servo drives, motors, bearings) as used and preferred by the licensor. However, the circumstances surrounding imports of these items were often as much due to the licensor's recommendation as to the possibilities of gaining discounts on purchases and responding to the demands of certain large customers. Some multinational customer companies narrowed down the licensor and licensee's freedom of sourcing components by listing their own approved suppliers. This occasionally hid nationalistic tendencies. It also represented a policy to achieve commonality in their plants throughout the world.

In the case of capital equipment purchases, the licensor's own or preferred make had often been imported, not because there was no equivalent available in the external market, but to ensure compatibility of systems between licensor and licensee.

B.27 Payments

Licensing is a negotiated transaction, the outcome depending on how well informed the two parties are about each other's position, the competitive situation with regard to the technology on offer compared with similar offers elsewhere, and sensitivities towards "up front" payments and "deferred" payments. It is not intended here to give a full exposition on the dynamics of bargaining. I was not present during negotiations and since executives in less than one third of licensor companies were actually met during the course of the study, the account would be biased in favour of the UK licensee and clouded by post facto rationalisations. Models for the negotiation of licence payments are to be found in the literature. It is my contention that these are too simplistic and lack the depth of understanding of political behaviour that could only be approached by a series of longitudinal studies. Thus the objective in this part of the study has been to explore the "unpackaging" of payments for inward licences and to identify some of the factors affecting the weighting of each element.

The form of payments in licence agreements is well established and normally involves some combination of the following:

(a) Down payments on release of the documented part of the technology (eg engineering drawings, machine specifications, parts/process schedules, instruction manuals).

(b) Progress payments leading up to commissioning one or more machines to the licensor's specification.

(c) Minimum annual royalty payments are sometimes applied on a stepped basis over the first 2-3 years as an incentive to the licensee to enter the market as quickly as possible or as a punitive measure over the full duration of the agreement in the event of non-performance. Minimum royalties may be inflation-adjusted according to some mutually agreed price index and often go hand-in-hand with exclusivity.

(d) Running royalty payments are normally expressed as a percentage of invoiced sales price or net selling price, or as a fixed sum of money per unit of output. Percentage royalty rates tend to be preferred because they are automatically adjusted for inflation in the licensee's country.

Tables 17 and 31 set out the incidence of each of the above elements in agreements and the breakdown of running royalties by technological segment. Further disaggregation was avoided to preserve the anonymity of companies active in turning and grinding technology where there were only three inward licence agreements in each segment.

Down payments were included in 10 (32%) agreements and ranged from £2,500 to £300,000 (adjusted to 1983 currency). Part payments were found in only 2 agreements. One involved three amounts, one lump sum on signing and the others at the end of the first and second years. The second agreement required a first payment on signing and a second smaller amount on completion of the tooling phase.

The acceptability, in principle, of downpayments by UK licensees raised the full spectrum of responses from executives and there was not always unanimity at board level. Some executives were vehemently opposed to up-front payments of any kind and saw them as 'lack of trust' in the licensee and a 'grab and run' tactic. This attitude was more prevalent in manufacturers of metal forming machines and may be partially related to custom and practice within that segment of "one-off" international licensing of designs where all payments tend to be wrapped into a single royalty on completion of the order. However, such strongly held views were inconsistent with their position as manufacturers and sellers; their terms of sale requesting stage payments to assist in financing work in progress! A second reason for opposition to down payments was the status of several licensees as the prior distributor of the licensor. Executives in these cases felt that a degree of product know-how had already been transferred and it would be impertinent of the licensor to request a lump sum at that stage in the relationship. Executives in 4 licensee companies said that down payments had been imposed on them.

Executives willing to concede that a down payment might have been a reasonable request from the licensor to cover the cost of transferring know-how during start-up, were more concerned about the actual magnitude of the payment. Discussions from hereon followed a convoluted and

Table 31. Breakdown of Running Royalty Payments by Technological Segment

	Turning	Milling	Grinding	Metal Forming	Automation	Total
Number of Agreements	3	7	3	7	11	31
Mean running royalty (%)	5.0	4.8	7.2	4.9	6.4	5.7*

Note : * The running royalty rate was not disclosed in the case of two agreements, one in milling and one in metal forming technology; and two agreements involved royalty payments in the form of a fixed sum per unit. The overall mean royalty of 5.7% is therefore based on N=27 (SD=2.2).

sometimes embarrassing path, as opinions on the purpose of down payments emerged. Small down payments of less than £5,000 were regarded as an administrative cost and not a point of contention. It was the extent to which licensors should base the payment on complexity and modernity of the technology, and attempts to recover "sunk" development and commercialisation costs that proved the most controversial. Executives generally had a sound grasp of all these issues. There was, for example, no disputing the higher costs to the licensor of transferring manufacturing-intensive know-how and the difference between licences for mature and "state-of-the-art" technology; but they struggled with intangibility and soon resorted to 'intuition' and 'professional judgement'. In the same way as executives' estimation of their own cost of assimilating the technology left a lot to be desired, it was observed that there was much to be gained from licensees putting themselves in the licensor's shoes.

Strongly held beliefs about how to approach the payment question invariably found expression in "rules of thumb" and simple payback calculation. One executive said that down payments should not exceed twice the selling price of the licensed machine. Another suggested one year's projected royalty payment as a useful guide. In practice these amounted to the same thing. It was suspected that the guidelines were formulated (or rationalised) a long time after negotiations had been concluded. In only 5 cases was there any clear indication of attempts to use discounting techniques related to the time value of money. The prevailing view on royalty payments was that 5 per cent of invoiced sales price was 'about right' with higher percentages for product uniqueness and lower for mature products.

Discussions on the magnitude of down payments could not be completely divorced from considerations of running royalty payments as several executives regarded them as interchangeable. Given flexibility to trade off reductions in down payments for a marginal increase in royalty rate, some executives in SBUs of large groups felt on safer ground when seeking corporate approval: (a) because royalties represent a deferred expense which aids cashflow and most importantly, is within executive control, and (b) because capital payments normally attract greater corporate scrutiny. One extreme extension of this behaviour was the managing director of a US-owned subsidiary who was pleased to have negotiated an inward licence agreement which involved only running royalty payments. The percentage rate was over three points above the mean for technological segment but was certain to find favour in the US parent company because the vice-president, to whom he reported, was sensitive about capital expenditure as it provided the basis on which his annual bonus compensation was computed.

Establishing an opening bid and setting an acceptable upper threshold appears to have been a hit and miss exercise in large and small SBUs alike. As one managing director of a small independent machine tool manufacturing company who had recently completed negotiations on a licence agreement for the first time explained: 'They wanted 7 1/2 per cent royalty and a 10,000 down payment but I got them down to 5 per cent and 5,000'. He was happy that a compromise had been reached and the technology had satisfied his expectations. Like many other licensees he felt that he could 'afford the down payment' and 'bear the royalty payment in his margins'.

Evidence from an historical study of postwar licences and from agreements current in 1984, showed that royalty rates were generally higher in the 1950's and 60's. This was probably due to (a) the lower intensity of price competition at the time, (b) the absence of Japanese machine tool manufacturers and competition from Taiwan, Korea and other newly industrialised countries, and (c) the dominance of manufacturers in one country, the USA, as suppliers of technology. The highest running royalty rate discovered in any agreement during the course of this empirical study was 15 per cent (1964) and the lowest below 1 per cent (1975). Of those agreements which had been in existence for more than 10 years, royalty payments had normally been maintained at the agreed rate on signing, reduced on a step basis or renegotiated downwards. Only two cases of increased royalties were found. One had exceptional circumstances involving extension of the scope of the licence to include a more sophisticated machine with a well known trade name. The second reflected the isolation that some small/medium sized companies experience when pursuing a negotiated settlement. When the Head of SBU in the latter company was asked about the increased rate he replied that they had drifted into it ....'with hindsight, the original x per cent on selling price was a high royalty and the current y per cent very high .... We didn't know what to expect'.

The imposition of minimum royalty requirements received similar negative comment as in the questioning on down payments. They were not liked, but tolerated in 7 agreements. Two licensees of long standing had such low demand during the recession of 1980-84 as to find themselves paying the minimum royalty. The actual sums of money paid were low but it was an event which had seemed highly unlikely on signing the agreement.

Several features surrounding the compromise on running royalty rate were present in some agreements and known to have been rejected during the negotiation of others:

(a) Different rates for spares, refurbished machines, tooling and accessories: This was one of the sticking points in certain agreements because it provided lucrative business during economic recession. It was not unusual to find a higher royalty rate on spares, in one case twice the rate of complete machines; and lower rates for repair, refurbishment and tooling. In one case, the licensor had offset the cost of stock-holding incurred by the licensee in recognition of the importance of spares and after sales service.

(b) Different rates for different models: The potential for bargaining on this issue was alluded to in the earlier discussion on scope of agreements. Only one current agreement contained such a division, based on mechanical and hydraulic machines. Imposition and acceptance of a blanket rate without thorough consideration of product mix was widespread and the potential for other permutations such as a single rate for common modules with different rates for "customised" items was seldom explored. Irrespective of whether this would have been acceptable to the licensor, the exercise would have quantified the cost of administrative convenience. Most UK machine tool manufacturers have strength in customisation and adaptation know-how and there is sound argument that with the exception of certain applications know-how, they should not have to pay a licensor for its use.

(c) No cases were identified of foreign licensor companies negotiating equity holdings in their UK licensees as a substitute for down payments or to offset royalties. One licensor had held a 14 per cent stake in the UK licensee for some years. This was the legacy of restructuring and change of ownership rather than due to a straightforward licensing arrangement. Conversely, two UK licensees had minority equity holdings in their licensor company. The seat on the board accompanying the investment was felt to bring participation in decision making and greater stability to the licensing agreement. But from thereon, the business philosophies of the two licensees diverged. In one case the initial cash stake on signing the inward licence agreement was almost doubled later when an option for further investment was taken up. The aim of the UK licensee being to fund growth of the licensor. Equity participation in the second case was a complex combination of the UK company 'protecting an existing outward licence', which later turned into a cross-licence, and '....access to a foreign manufacturer active in the supply of machines in an expanding and competitive market (ie Japan)'.

(d) No differentiation between the transfer of "static" and "dynamic" (ongoing) know-how was found to be reflected in royalty rates. The rates were the same at the beginning of the agreed duration as towards the end, yet some licensees had noted the expiry of patents and a diminishing flow of know-how with the passage of time. The findings of this study suggest that the notion of royalties as a deferred payment may provide the simplest explanation. Since most machine tool licence agreements involve greater intensity of technology transfers at start-up, it may be that the value of know-how is "averaged" over the duration along with similar valuations of longer lasting industrial property rights in trade marks and copyrights.

Royalty rates were seldom a function of product range and uniqueness of the technology. The width of the product range seemed to make no difference within a given technology. But generalisations about uniqueness are questionable for two reasons: Firstly, design, reliability, maintainability, etc. are technological attributes which translate into product differentiation, which in turn can be enhanced in the market through the use of trade marks. UK licensees frequently spoke of how their licensed machine was the "Rolls Royce" of the segment in which they operated and they were prepared to accept a premium on royalty rate due to the use of trade marks and the absence of close competitors. Secondly, viewed from another angle, where uniqueness is coupled with leading edge technology, this is often accompanied by complexity, and lead time is of value. Royalty rates and down payments are affected by uniqueness and complexity of the technology in as much as they may shift the upper and lower threshold royalty rates which determine the flexibility zone for bargaining.

(e) The actual sums of money paid over to the licensor as royalties are a function of the royalty rate and the definition of selling price, ex-works price or some other base figure used to make the calculation. The extent to which this simple concept had eluded licensors and licensees during negotiation could not be determined with precision. Examination of the 29 agreements involving percentage running royalties revealed that the calculation was based on invoiced sales price in 15 cases, net selling price (ie less packaging, transport and distribution costs, duties, VAT) in 14 cases, and further deductions for components imported from the licensor and certain proprietary components in 12 cases. The importance of gaining these concessions cannot be over-emphasised as royalties may be requested on both the "bought-in" materials, components and services <u>and</u> on the "value added" portion of selling price. The former frequently exceeded the latter due to sub-contracting. Again, UK executives experienced in contract negotiation and well down the learning curve for licensing had used this to advantage.

(f) Territory restrictions seemed to have influenced the magnitude of royalty payments only in respect of home market exclusivity. The absence of exclusivity would almost certainly have caused most licensees to withdraw from negotiations. Assessing their sensitivity to further trade-offs in royalty rate based on an hierarchy of exclusive and non-exclusive sales territories was problematic. Having extracted the territory rights in agreements for discussion, few executives could justify the inclusion of particular territories and very little market research had been carried out to establish their fertility for sales of licensed machines.

8.23 Termination and Expiry

Licence agreements normally state an expiry date, together with provisions for the handling of disputes, arbitration and termination. The existence of an expiry date, as opposed to an indefinite arrangement, reinforces the permanence of the licence.

Executives' views on expiry and termination were sought because it placed a different perspective on the technology package by allowing further exploration of what they regarded as their company's "core" technology. Particularly revealing were comments on (a) the extent to which some licensees were dependent on their foreign licensor, (b) how this fitted in with the licensor's aspirations and objectives, and (c) the propensity of the parties to seek recourse to litigation.

The first area to be explored concerned the rights and obligations that might survive termination or expiry of licence agreements. This was especially pertinent to the 10 agreements that were within 1 year of expiry and the further 10 within 2 years listed in Table 29. In some of these cases, the question was timely as they had decided not to negotiate extension of the agreement and wished to continue manufacturing machines under their own name using what they deemed to be their own technology. Although the circumstances prevailing at the time varied widely, the interpretation hinged on the status of patents and know-how.

Two agreements each covered patents and improvement patents at different stages in their life, making it uncertain whether the effective duration could be extended by the licensor to the life of the most recent patent. Similarly, there was intense debate on the relative proportions of know-how that had been transferred permanently, that which the licensee was 'permitted to use' and was therefore repossessable by the licensor, and that which had entered the public domain. It was interesting to note that copyright in the drawings was felt to be of minor importance and dismissed by one executive in the comment ....'they can have those back along with the other items of documentation'. It was likely that near-perpetual obligations would not hold up in law and that in one case, the improvement patents were weak and supporting a mature product. Nevertheless, both licensees appeared resigned to compromising on a reduced royalty fee for several years as the worst outcome.

The question of premature termination frequently provoked instant reactions, such as: ....'it couldn't happen in our case' or ....'we would sue for breach of contract'. It was only when it was put to executives that termination might arise through default and conflict of interest, perhaps due to unacceptable successors in business as the outcome of an acquisition or merger, that consideration of vulnerabilities and contingency plans entered the discussion. One executive in a UK licensee company, for instance, indicated that he had recently signed an agreement with a foreign licensor, only to find three months later that the company had fallen into receivership and the attitude of the new owner was unsympathetic. Such matters of termination before the agreement has run its natural course are covered by appropriate clauses in the agreement. Normally, the onus would be placed on each party to prove default or for them to arrive at some mutual understanding. Executives were ill-prepared for events of this kind and generally frightened by the threat of litigation. This was particularly noticeable among executives in small/medium-sized licensee companies. While they were not inhibited in seeking external legal aid in perusing the terms of the agreement before signing, they clearly felt disadvantaged compared with the corporate resource available to their licensors.

B.24 Cross-Licensing

As the cost of machine tool design and development has risen, some executives have considered ways of sharing and exploiting technology with foreign partners. One mechanism for doing this without necessarily entering into a relationship involving equity ownership is through cross-licensing. Put simply, the partners agree to manufacture and sell under licence each others' selected complementary machines in defined markets.

The two-way flow of technology may involve reciprocal access to patents, designs and know-how without payment taking place, but the exchange process is more likely to be formalised by separate inward and outward licences in parallel. The last point is a sound one commercially because different companies and markets tend to change at different rates. There is a lower probability of conflict arising at a later date if any imbalance is built into the flow of royalties accruing from sales of machines based on the respective technologies.

Cross-licensing, as a bilateral mode of international technology transfer, is poorly developed in machine tools compared with other industries such as electronics, chemicals and pharmaceuticals. This may be due to: (a) the relative ease with which concise designs, formulations and process instructions are transferred, often at "arms length", in the last three industries, and (b) because of their oligopolistic market structure and the dominance of multinational companies in the generation and exploitation of technology. Cross-licensing normally takes place between companies of equal commercial and technological standing.

Discussion on cross-licensing with senior executives in US and UK machine tool companies was a frustrating and almost fruitless exercise. Over half of the licensors and licensees interviewed fell into the "no opinion" category and there was a tendency to lump cross-licensing under the blanket term of "collaboration". US executives were very cautious of any transaction perceived as likely to fall foul of anti-trust legislation.

In the UK, cross-licensing was not found to be an option that had received much serious consideration. Only 4 cross-licensing arrangements for machine tools were discovered to be in operation during 1984. Due to assurances of confidentiality and anonymity the detailed product/market circumstances surrounding each cross-licensing case will not be divulged here. It is sufficient to record that in one arrangement of 10 years duration, the UK partner had achieved production of 50 machines per year up to 1980, when 'the market collapsed with the recession'. The licence got them into the market quickly but there was some disappointment at the lack of updated technology from the foreign licensor partner. In contrast, the foreign partner abandoned production of machines to UK designs after total sales of only 12 machines over about two years. Eventually, as the relationship became one-sided and the grounds for mutual interest receded, it was clear that the agreements would not be extended. It would be fair to say that the foreign partner had outgrown the UK partner in machine tool production capability and overall sales turnover.

The second case of cross-licensing was of 5 years duration and covered a range of equipment of low volume. The relationship seemed to have worked well over the first two years and both partners expressed some admiration for each other's capabilities. Unfortunately, a change of ownership by one of the partners made the possibility of renewal of the agreements remote as 'the relationship with the new owner had not gelled'. A potentially synergistic technological arrangement had been frustrated by a clash of personalities and business philosophies.

The third and fourth cases involved a UK manufacturer entering into cross-licensing arrangements with a Japanese and a US manufacturer. The inward agreement with the Japanese manufacturer was for 5 years duration and involved a minority share holding by the UK company. The agreement with the US manufacturer was originally for 10 years duration and had been extended for a further 10 years. Orders for equipment in both cases were intermittent and there were several competitors with similar technology worldwide. Competitive advantages from cross-licensing were described as a way of offering complete equipment packages and 'an opportunity to earn money'.

It is impossible to generalise beyond the experience of only four cases, except to observe that each UK company had succeeded in increasing its stock of knowledge and gaining additional business. All claimed to know their respective partners well before entering into cross-licensing. At the time of signing and over the course of the agreements, there was little to distinguish these cases from the conventional mode of one-way licensing.

B.3 TABLES AND FIGURES

The following set of Tables and Figures support earlier analysis in this Appendix.

Table 32. Summary of the Five Forces Affecting Competition in the Machine Tool Industry

Standard Machines	Customised Machines
(a) Industry Competitors: Intense rivalry due to a large number of competitors offering similar products.	Few competitors in highly sophisticated machining systems. Strong competition for sporadic orders. Loss of a few large orders may put the business in jeopardy.
(b) Potential Entrants: Low threat of new entrants. High barriers to entry due to experience/scale effects. Late entrants would require high investment in cost-saving technology and access to distribution channels.	New entrants would not possess required credibility and track record. Easy to enter unsophisticated end of the market on a "jobbing" basis.
(c) Suppliers: CNC systems dominated by a small number of suppliers in a global market. These suppliers also offer other key components in a package cocooned in guarantees.	Bargaining power of suppliers is high due to low usage of components in machine tools compared with other industries. Software services may be important in the future.
(d) Buyers: Greatest concentration is in automotive sector. Remainder spread across a wide range of engineering industries where switching is a possibility.	Highly concentrated in automotive sector. Some buying companies are backwardly integrated in automation systems. Others are attempting to set de facto standards in systems compatibility and controlling machine specifications.
(e) Substitutes: Main threat is from customised machines of similar type. Also substitution of machining processes (eg grinding for turning, electro-discharge machining for grinding).	Some customised machines are also "dedicated" machines. A threat has emerged from flexible machines.

Table 33. Summary of Critical Success Factors in the International Machine Tool Industry

Standard Machines	Customised Machines
Recognition that the main high volume segments for general purpose machines are increasingly commodity-like in a global market.	Performance to tight specifications. Customers seek machine reliability, productivity, after sales service to minimise down-time.
Price competitiveness. Production engineering skills are necessary to systematically drive down unit costs and support price sensitivity.	Applications engineering. High level of product engineering skills required to solve customer machining problems.
Machine reliability. Depends on rigorous specification and quality control of bought-in components. Assumes greater importance in manufacture/assembly of multi-function machines. Sales coverage through a network of distributors to assure availability on a global basis. Associated with strong commitment to building/defending market share.	Cost Containment. Preparing realistic proposals and controlling the manufacture of "specials" to avoid cost over-runs. Highly customised machines are moderately price sensitive. Customers pay attention to initial capital cost and operating costs over the service life of machine. Commercial skills in bidding/tendering and negotiating required, supported by market intelligence.
Market research. Vital to identify the width of product range and minimise overlaps between models.	Ordering patterns erratic. Close manufacturer/customer relationships ensure early warning of potential orders and changing customer requirements.
Credibility/image.	Credibility/image.

Table 34. Summary of Financial Performance of the Sample Companies for Years 1978-1986

*Index 1980=100

Company		1978	1980	1981	1982	1983	1984	1985	1986
Turning:									
Binns & Berry:	Sales(£m)	1.0	1.1	1.0	1.1	1.3	1.4	1.5	1.3
	ROS (%)	6.9	3.2	(3.4)	(1.8)	(0.2)	1.4	2.1	6.4
	ROCE (%)	34.0	10.4	(11.4)	(6.9)	(1.0)	5.9	7.9	9.5
	*Sales(£m) Inf Adj	1.4	1.1	1.0	1.0	1.0	1.0	1.0	0.9
BQ		consolidated accounts					2.0 est	closure	
Brown & Ward			0.85	0.53	0.82	0.59	closure		
				(28.5)	(0.6)	(1.9)			
				(47.9)	(1.6)	(3.7)			
			0.85	0.49	0.70	0.48			
Colchester Lathes		20.1	28.6	21.3	15.7	14.5	13.9	22.3	28.7
		7.7	3.5	3.3	(4.6)	(4.0)	(15.0)	(0.2)	2.1
		12.9	7.2	5.0	(6.4)	(10.2)	(27.3)	(0.6)	7.3
		26.9	28.6	19.8	13.6	11.8	10.4	15.4	18.7
Dean, Smith & Grace		6.5	10.4	8.8	6.5	4.9	6.3	7.2	8.1
		9.2	7.2	(3.2)	(7.7)	(31.3)	(10.1)	2.3	(0.9)
		15.5	13.8	(5.4)	(10.5)	(50.6)	(18.3)	4.9	(2.1)
		8.7	10.4	8.2	5.6	4.0	4.7	5.0	5.3
EMI-MEC		7.7	12.9	6.7	5.4	3.0	4.5	6.4	4.8
		26.5	19.0	10.9	5.1	(21.5)	(20.9)	(1.9)	(5.1)
		87.3	94.1	19.0	10.2	(34.4)	(39.7)	(5.2)	(17.9)
		10.3	12.9	6.2	4.7	2.4	3.4	4.4	3.1
T S Harrison		8.8	11.4	9.7	5.8	7.4	8.4	10.0	12.0
		16.7	14.7	5.7	(10.6)	(1.8)	2.6	9.7	11.8
		34.8	32.7	4.9	(6.0)	(5.5)	16.6)	34.0	11.9
		11.8	11.4	9.3	5.0	6.0	6.3	6.9	7.8
Hepworth		consolidated accounts							

Key : Under each company heading, the first line = sales turnover (£m),
second line = return on sales (%),
third line = return on capital employed (%),
fourth line = inflation adjusted sales turnover (£m) 1980=100

Table 34 (continued)

Company	1978	1980	1981	1982	1983	1984	1985	1986
T I Matrix	49.0	5.9	6.6	7.3	8.8	11.8	24.5	N/A
	3.7	(0.9)	(29.9)	3.4	(7.9)	(8.2)	(15.3)	
	7.4	(2.9)	(26.8)	3.5	(25.2)	(53.6)	(66.8)	
	65.6	5.9	6.1	6.3	7.1	8.9	16.9	
Warner & Swasey	7.3	8.9	7.8	7.2	3.9	abandoned		
	17.3	10.9	(9.6)	(79.2)	(13.5)	manufacturing in		
	18.5	10.8	(7.8)	(159.3)	(1.3)	UK		
	9.8	8.9	7.2	6.2	3.2			
WCI (formerly a division of Alfred Herbert)	consolidated accounts							
Wickman	8.0	10.3	19.3	10.8	N/A	divested		
	10.8	7.9	4.0	(32.4)				
	49.0	31.3	31.4	N/A				
	10.7	10.3	18.0	9.3				
<u>Milling:</u>								
Ajax	N/A	N/A	N/A	3.1	4.9	5.2	6.3	6.7
				(3.2)	2.0	4.7	6.2	6.4
				(8.5)	9.2	21.0	40.0	45.0
				2.7	4.0	3.9	4.3	4.4
W Asquith (start-up 1981)			0.5	2.3	2.7	2.9	4.4	3.7
			(10.0)	(0.1)	5.1	(8.2)	4.0	0.1
			(10.9)	(0.9)	(21.3)	(104.9)	17.0	0.3
			0.5	2.0	2.2	2.2	3.0	2.4
Bridgeport	consolidated accounts (est 40m sales in 1986/87)							
Cincinnati Milacron	36.2	46.7	41.1	30.9	27.1	28.5	25.3	28.8
	8.9	9.1	(12.5)	(5.3)	(0.2)	1.0	(2.8)	(2.0)
	15.8	16.1	(22.0)	(8.0)	(0.2)	1.4	(3.9)	(3.0)
	48.4	46.7	3.8	26.7	22.0	21.4	17.5	18.7
De Vlieg (formerly a division of Alfred Herbert)			6.3	8.8	2.6	3.2	6.3	9.0
			14.6	8.3	(74.8)	(28.2)	2.9	5.1
			30.0	14.1	(58.2)	(36.8)	6.6	15.0
			5.9	7.6	2.1	2.4	4.3	5.9

Table 34 (continued)

Company	1978	1980	1981	1982	1983	1984	1985	1986
G & L-F	7.7	10.3	11.6	7.8	8.5	5.3	8.2	N/A
	10.6	11.9	5.1	(2.6)	(10.2)	(30.6)	1.6	
	13.8	17.3	7.7	(9.2)	(17.9)	(47.0)	3.3	
	10.3	10.3	10.8	6.7	6.9	4.0	5.7	
Hurco				16.2	3.1	4.5	6.8	10.0
				(4.8)	(14.5)	(18.1)	(51.3)	N/A
				6.6	(2.2)	(24.0)	N/A	N/A
				14.0	2.5	3.4	4.7	6.5
KTM	15.1	24.6	25.7	21.8	13.8	8.8	16.6	20.8
	9.9	10.8	(1.2)	(4.9)	(17.3)	(33.4)	0.7	1.2
	18.3	26.2	(2.9)	(12.8)	(56.6)	(52.3)	1.9	4.9
	20.2	24.6	23.9	18.8	11.2	6.6	11.4	13.5
Kearas-Richards	management buyout from						N/A	N/A
	Staveley Industries 1983						N/A	N/A
							33.5	14.1
J Parkinson	2.4	2.0	2.9	2.0	1.7	2.2	closure	
	4.9	(1.7)	(0.9)	(3.7)	(2.9)	(12.3)		
	9.4	(1.8)	(0.9)	(2.6)	(1.7)	N/A		
	3.2	2.0	2.7	1.7	1.4	1.7		
Pollard	4.8	5.8	5.3	3.9	3.4	4.7	6.0	6.6
	16.2	15.7	4.3	(1.4)	1.2	8.3	4.0	3.1
	33.9	27.5	6.6	(1.6)	1.2	10.8	6.5	5.3
	6.4	5.8	4.9	3.4	2.8	3.5	4.1	4.3
Wadkin	consolidated accounts							
Grinding:								
AMT	0.6	0.9	1.0	1.1	1.6	2.4	3.2	2.9
	0.4	1.7	2.4	65.0	(3.7)	4.5	4.0	2.4
	N/A	N/A	N/A	N/A	(6.7)	11.6	13.2	8.1
	0.8	0.9	0.9	1.0	1.3	1.8	2.2	1.9
Catmur	2.2	2.6	2.3	2.2	2.0	N/A receivership		
	3.8	0.5	(5.9)	(1.6)	(1.9)			
	22.6	(2.0)	(25.8)	(8.3)	(10.7)			
	2.9	2.6	2.1	1.9	1.6			

Table 34 (continued)

Company	1978	1980	1981	1982	1983	1984	1985	1986
Jones & Shipman	17.0	22.2	16.7	13.8	13.6	16.9	19.9	21.0
	17.2	9.7	3.8	(7.8)	(5.5)	6.3	10.7	11.0
	29.4	16.7	5.0	(9.7)	(7.6)	10.0	17.5	17.4
	22.7	22.2	15.5	11.9	11.0	12.7	13.7	13.7
Keighley Grinders	2.5	4.4	merged with Newall					
	15.6	0.4						
	35.0	1.2						
	3.3	4.4						
Landis Lund	6.7	9.8	10.7	10.2	9.6	5.6	7.1	N/A
	32.3	29.5	27.2	25.4	16.2	6.2	7.9	
	36.6	43.6	42.2	35.1	20.2	4.6	8.8	
	9.0	9.8	10.0	8.8	7.8	4.2	4.9	
Newall	10.5	14.3	14.5	10.9	10.5	7.8	12.5	N/A
	12.8	6.0	1.4	(5.1)	(10.6)	(12.3)	0.0	
	26.9	13.1	3.1	(11.1)	(40.5)	(65.6)	0.0	
	14.0	14.3	13.5	9.4	8.5	5.9	8.6	
Oerlikon	3.0	5.0	4.6	3.6	11.0	est	closure	
	7.5	8.6	1.2	(5.0)				
	15.1	20.9	2.1	(5.9)				
	4.0	5.0	4.3	3.1				
Metal Forming:								
E W Bliss	2.9	3.2	3.1	2.9	2.5 est			
	15.1	(1.4)	8.0	0.6				
	9.7	(0.8)	5.1	0.3				
	3.9	3.2	2.9	2.5				
Henry Berry	consolidated accounts							
Bronx	12.2	14.8	7.5	13.5	10.4	7.1	22.1	N/A
	2.6	3.4	(11.8)	4.0	2.0	(9.0)	4.2	
	9.3	11.6	(28.1)	15.4	5.9	(23.2)	13.6	
	16.3	4.8	7.0	11.7	8.5	5.3	15.2	
Davy McKee	consolidated accounts							

Table 34 (continued)

Company	1978	1980	1981	1982	1983	1984	1985	1986
Ex-Cell-O	2.2	7.0	5.5	8.8	9.8	6.6	7.6	N/A
closure 1987	19.2	22.1	2.7	(5.4)	(8.6)	(1.7)	2.9	
	22.5	37.4	3.3	(11.9)	(26.6)	(3.7)	N/A	
	2.9	7.0	5.1	7.6	8.0	5.0	5.2	
GEC Robotics			0.9	1.4	1.2	0.8	0.7	N/A
(start up in 1981)			(63.3)	(24.2)	(46.3)	(1.8)	(4.6)	
			N/A	N/A	N/A	N/A	N/A	
			8.3	1.2	1.0	0.6	4.8	
Kingsbury		8.5	7.1	6.1	7.4	10.3	N/A	N/A
		0.7	(3.4)	(1.5)	2.3	7.3		
		1.3	(5.5)	(2.4)	4.1	15.5		
		8.5	6.6	5.3	6.0	7.7		
LaPointe	consolidated accounts							
PGM	2.9	4.3	4.1	3.3	3.5	closure of machine tool operations		
	8.6	8.8	(1.5)	(31.0)	(29.4)			
	15.5	16.8	(2.1)	(37.9)	57.1)			
	3.9	4.3	3.8	2.9	2.8			
Rediffusion	consolidated accounts							
Systems Control				0.3	0.5 est	N/A	N/A	N/A
600 Fanuc					0	0.4	0.9	1.0
					-	(81.3)	(28.2)	(30.6)
					N/A	N/A	N/A	N/A
						0.3	0.6	0.7
Unimation	0.7	2.9	3.2	6.7	8.7	7.6	12.1	N/A
	33.8	(5.5)	(20.0)	7.9	(20.4)	(26.7)	(22.2)	
	0.9	2.9	3.0	5.8	7.1	5.7	8.3	
V S Remek (start up in 1981)				0.8	0.1	acquired by VS Group		
Wavis	3.5	4.7	5.9	4.1	5.0	3.7	3.5	4.4
	10.8	6.7	14.1	(5.4)	3.4	2.3	(1.1)	9.4
	25.5	13.0	26.5	(7.4)	5.4	2.7	(1.3)	13.2
	4.7	4.7	5.5	3.5	4.1	2.8	2.4	2.9

Table 35. Age Profile of Senior Executives in Machine Tool Manufacturing SBUs as at 1984

	Average Age (years)	Range (years)
Head of SBU (N=54)	51	36-64
Marketing/Sales Directors (N=31)	47	34-63
Engineering/Technical Directors (N=30)	50	33-65
Manufacturing/Production Directors (N=28)	49	26-67

Table 36. Continuity at SBU Board Level

	Number of Years in Post as at 1984					Total
	<1	2-3	4-5	6-10	10+	
Heads of SBU	8	13	12	8	13	54
Marketing/Sales Director	3	6	2	2	18	31
Engineering/Technical Director	2	6	2	4	16	30
Manufacturing/Production Director	2	5	1	1	19	28

Table 37. Frequency of Overseas Visits by Senior Executives in UK-Owned and US-Owned SBUs for Years 1981-83

	To Europe	To Japan	To USA
UK-Owned SBUs:			
Head of SBU (N=32)	$\bar{x}$=8.2 SD=6.5 Range=0-20	$\bar{x}$=0.9 SD=1.7 Range=0-8	$\bar{x}$=3.7 SD=3.0 Range=0-15
Marketing/Sales Directors (N=18)	$\bar{x}$=13.8 SD=9.1 Range=2-40	$\bar{x}$=1.1 SD=2.2 Range=0-8	$\bar{x}$=4.3 SD=6.3 Range=0-15
Engineering/Technical Directors (N=16)	x=6.6 SD=7.2 Range=0-30	$\bar{x}$=6.3 SD=1.6 Range=0-6	$\bar{x}$=2.3 SD=3.0 Range=0-6
Manufacturing/Production Directors (N=15)	$\bar{x}$=3.8 SD=8.3 Range=0-15	$\bar{x}$=0.5 SD=1.5 Range=0-6	$\bar{x}$=0.7 SD=2.6 Range=0-10
US-Owned SBUs:			
Head of SBU (N-18)	x=12.2 SD=6.9 Range=0-25	$\bar{x}$=0.9 SD=2.4 Range=0-10	$\bar{x}$=7.5 SD=9.4 Range=0-16
Marketing/Sales Directors (N=10)	$\bar{x}$=13.0 SD=9.5 Range=0-30	$\bar{x}$=0.4 SD=0.7 Range=0-2	$\bar{x}$=3.7 SD=4.5 Range=0-13
Engineering/Technical Directors (N=10)	$\bar{x}$=3.0 SD=3.8 Range=0-10	$\bar{x}$=0.2 SD=0.4 Range=0-1	$\bar{x}$=2.8 SD=2.8 Range=0-8
Manufacturing/Production Directors (N=13)	$\bar{x}$=1.3 SD=2.6 Range=0-8	$\bar{x}$=0 SD=0 Range=0	$\bar{x}$=0.9 SD=1.9 Range=0-6

Key: N = Number of usable responses, $\bar{x}$ = average number of visits.

Table 38. Participation/Attendance at Major International Trade Shows By Senior Executives in UK-Owned and US-Owned SBUs for Years 1981-83

Trade Show	Exhibiting Through Parent, Own SBU, Distributor or Licensor/Licensee	Number of SBUs Sending Visitors	Number of Visitors per SBU
UK-Owned SBUs:			
Chicago	SBU 4, Dist 3, Lic 3	7	$\bar{x}$=4, SD=3, Range=1-15
Hanover	SBU 8, Dist 2, Lic 0	19	$\bar{x}$=5, SD=4, Range=1-20
Osaka	SBU 0, Dist 1, Lic 3	4	- - Range=1-2
Paris	SBU 8, Dist 2, Lic 0	18	$\bar{x}$=6, SD=4, Range=1-25
US-Owned SBUs:			
Chicago	Parent 15, Dist 1, Lic 0	13	$\bar{x}$=6, SD=5, Range=1-20
Hanover	Parent 9, Dist 2, Lic 0	11	$\bar{x}$=11, SD=9, Range=1-41
Osaka	Parent 3, Dist 0, Lic 6	2	- - -
Paris	Parent 7, Dist 1, Lic 0	12	$\bar{x}$=7, SD=5, Range=1-20

Table 39. Estimated National Shares of World Machine Tool Production for Years 1965-1987

Country	1965 (%)	1974 (%)	1981 (%)	1983 (%)	1985 (%)	1987 (%)
W Germany	17.5	17.8	15.3	15.7	14.2	19.9
Japan	4.1	12.9	18.2	18.6	24.0	20.5
Switzerland	3.2	3.6	3.1	3.9	4.4	4.7
UK	8.2	4.6	3.5	3.1	3.7	3.0
Italy	2.6	6.1	5.3	5.2	4.8	6.8
France	N/A	N/A	3.1	2.7	2.1	2.3
USA	28.4	16.9	19.5	9.9	11.7	7.8
USSR	14.9	14.6	12.2	16.0	13.8	12.7
E Germany	N/A	N/A	2.9	4.4	3.6	4.2

Source : American Machinist, OECD, NMTBA

Table 40. Estimated National Shares of World Machine Tool Exports for Years 1965-1987

Country	1965 (%)	1974 (%)	1981 (%)	1983 (%)	1985 (%)	1987 (%)
W Germany	27.2	31.0	24.2	23.0	20.0	22.6
Japan	3.3	6.5	16.4	15.1	22.1	20.0
Switzerland	7.5	8.0	7.0	8.3	8.8	9.3
UK	7.5	5.3	4.7	4.1	3.6	3.4
Italy	5.5	6.5	6.8	7.1	6.4	7.6
France	N/A	N/A	3.8	N/A	2.4	N/A
USA	14.1	9.6	11.1	4.6	4.7	7.8
USSR	14.9	14.6	12.2	16.0	13.8	
E Germany	9.0	10.9	5.3	8.5	7.8	8.1

Source : American Machinist, OECD, NMTBA

Table 41. International Comparison of Imports of Foreign Machine Tools as a Share of Domestic Consumption for Years 1963-1988

Country	Year 1963 (%)	1975 (%)	1980 (%)	1985 (%)	1988 (%)
W Germany	5.2	13.8	23.2	32.6	35.8
Japan	21.9	14.2	8.5	6.5	7.1
Switzerland	N/A	40.9	55.1	58.9	61.7
UK	26.0	37.7	45.3	47.4	47.4
Italy	N/A	32.4	29.2	30.3	25.7
USA	5.2	13.8	23.2	44.7	52.3

Source : VDW, CECIMO
Note : Apparent Domestic Consumption=Production-Exports+Imports

Table 42. International Comparison of Exports of Machine Tools as a Share of National Production for Years 1966-1988

Country	Year 1966 (%)	1975 (%)	1980 (%)	1985 (%)	1988 (%)
W Germany	54.9	72.7	62.5	60.8	61.9
Japan	19.1	29.5	38.1	39.8	38.9
Switzerland	67.4	81.7	87.2	87.3	87.2
UK	29.4	49.9	60.8	44.1	45.8
Italy	63.0	48.4	49.1	57.9	39.2
USA	12.9	23.2	21.8	17.3	24.6

Source : VDW, CECIMO

Table 43. Machine Tool Patenting Activity in the USA by Foreign Manufacturers, 1966-81

	Patents Granted and Shares							
	1966		1971		1976		1981	
Country	No	(%)	No	(%)	No	(%)	No	(%)
W Germany	129	(29.6)	262	(28.2)	152	(23.3)	193	(27.8)
Japan	28	(6.4)	124	(13.3)	131	(20.1)	160	(23.0)
Switzerland	26	(6.0)	55	(5.9)	36	(5.5)	27	(3.9)
UK	98	(22.5)	135	(14.5)	78	(12.0)	67	(9.6)
Italy	12	(2.8)	32	(3.4)	22	(3.4)	25	(3.6)
France	45	(10.3)	85	(9.1)	52	(8.0)	32	(4.6)

Source : Science Policy Research Unit, University of Sussex. Cited in Jones, D.T. (1983). Machine Tools: Technical Change and A Japanese Challenge. Ch 8 in Shepherd, G. Duchene, F & Saunders, C. Europe's Industries. Frances Pinter, London p204.

Table 44. UK Production of Machine Tools By Value for Years 1960-1988

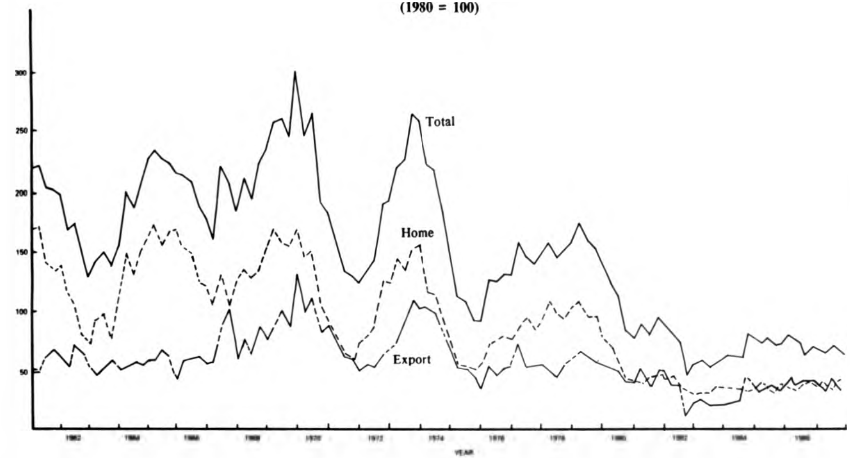
Year	Production (£m)	Index* (1980=100)	Inflation-Adjusted Production (£m)
1988	842	165.0	510
1987	652	159.3	409
1986	614	153.7	399
1985	606	145.0	418
1984	497	133.2	373
1983	413	123.1	335
1982	477	115.7	412
1981	434	107.4	404
1980	593	100.0	593
1979	549	85.0	467
1975	317	47.8	663
1970	219	21.8	1005
1960	95	14.4	660

Source : Department of Trade & Industry and Machine Tools Trades Association based on Activity Heading 3221.

Note : * Index based on the annual average of quarterly producer price indices for metalworking machine tools published by the Business Statistics Office.

Figure 4 **Quarterly Volume Index of New Orders for Machine Tools**

(1980 = 100)



Source: Business Monitor PQ3221

Table 45. Breakdown of Employment in the UK Machine Tool Industry for Years 1978, 1984, and 1988

Occupation	Number of People in Occupations 1978	1984	1988
Managerial staff	2366	1475	1727
Scientists/Technologists	277	195	348
Technicians/Draughtsmen	4476	1930	2125
Administrative/Professional Staff	2146	955	1220
Clerical	5605	1942	1941
Supervisors/Foremen	2149	925	943
Craftsmen	16932	6715	7442
Operators/Other	13325	4634	4868
Total	47276	18771	20614

Source : Engineering Industry Training Board Statutory Returns for Activity Heading 3221

Table 46. Index of Production and Employment for the UK Machine Tool Industry 1979-1988

Year	Index of Production (1985=100)	Index of Employment (1985=100)
1979	133	-
1980	128	-
1981	88	135 est
1982	81	125
1983	72	109
1984	83	98
1986	98	98
1988	113	100

Source : Department of Employment and Department of Trade & Industry

Table 47. UK Exports and Imports of Machine Tools for Years 1960-1988

Year	Exports (£m)	Imports (£m)	Exports / Imports
1988	386	411	0.94
1987	306	323	0.95
1986	269	381	0.71
1985	266	304	0.87
1984	226	256	0.88
1983	210	194	1.09
1982	273	234	1.17
1981	281	213	1.32
1980	292	268	1.09
1979	223	285	0.78
1975	164	115	1.43
1970	88	57	1.55
1960	28	22	1.26

Source : Overseas Trade Statistics and HM Customs & Excise

Table 48. The EEC as a Source of UK Imports and Destination of UK Exports for Years 1972-1988

Year	EEC as a Source of UK Imports(%)	EEC as a Destination of UK Exports (%)
1988	42	38
1986	45	32
1984	49	24
1982	49	20
1980	48	26
1978	53	20
1976	48	20
1974	54	24
1972	52	25

Source : HM Customs & Excise
Stastics include both new and used machines

Table 49. UK Production of Machine Tools By Value for the Five Main Technological Segments for Years 1980-1988 (*Index 1980=100)

Machine Tool Technology	Year				
	1988	1986	1984	1982	1980
Turning:					
Production (£m)	72	76	60	83	135
Inf Adjusted* (£m)	44	49	45	72	135
% CNC	37	46	50	47	23
Milling:					
Production (£m)	113	82	46	41	60
Inf Adjusted* (£m)	68	53	35	35	60
% CNC	88	85	69	46	35
Grinding:					
Production (£m)	37	35	27	34	69
Inf Adjusted* (£m)	26	23	20	29	69
Metal Forming:					
Production (£m)	86	88	68	82	114
Inf Adjusted* (£m)	52	57	51	71	114
Automation+ :					
Production (£m)	34	23	21	51	46
Inf Adjusted* (£m)	21	15	16	44	46

Source : Business Monitor PQ332 up to 1982 and PQ3221 thereafter.

Notes : + Statistics for "unit construction" and single/multi-station transfer lines only.

The MTTA estimates that the above data captures only about 60-70 per cent of machine tool production.

Table 50. International Comparison of the Growth in Industrial Robot Population for Years 1980-1988

Year	Cumulative Number of Robots Installed					
	UK	Japan	USA	France	W Germany	Italy
1988	5034	176000	32600	8026	17700	8300
1986	3683	1160001	25000	5270	12400	5000
1984	2623	67000	13000	2750	6600	2600
1982	1152	32000	7000	1385	3500	1000
1980	371	N/A	N/A	N/A	1255	N/A

Source : International Federation of Robotics.

Table 51. Country of Origin of Industrial Robots Installed in the UK for Years 1982 and 1988

Country of Origin	Robots Installed			
	1982		1988	
	Number	(%)	Number	(%)
UK	101	23	277	38
Japan	110	25	136	18
USA	64	15	13	2
W Europe (exc UK)	164	37	308	42
Total	439	100	734	100

Source : International Federation of Robotics and British Robot Association

Table 52. Country of Origin of Industrial Robots Installed in the UK for Year 1988 By Price Range

Country of Origin	Robots Installed	Robots Installed in a Given Price Range			
		<£10000	£10-20000	£20-30000	>£35000
UK	277	47	152	55	23
Japan	136	35	2	60	39
USA	13	8	1	2	2
W Europe (exc UK)	308	53	109	84	62
Total	734	143	264	201	120

Source : British Robot Association

Table 53. UK Applications for Industrial Robots for Years 1982 and 1988

Robot Application	Robot Population	
	1982 (%)	1988 (%)
Machine loading	10	12
Arc welding	14	13
Injection moulding	14	20
Assembly	3	10
Education/research	3	6
Handling	4	4
Spot welding	22	12

Estimated total UK expenditure for 1988 = £30m

Source : British Robot Association

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