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**SWP 13/91 DETERMINING A TECHNOLOGY STRATEGY FOR
COMPETITIVE ADVANTAGE**

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**Presented at the 4th annual conference of the British Academy of Management on 10/11
September 1990 at Glasgow Business School.**

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Autumn 1990

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To be presented at the 4th annual conference of the British Academy of Management to be held on the 10th and 11th September 1990 at the Glasgow Business School.

INTRODUCTION

The management of technology first became an explicit element of management practice and strategy at the end of the 19th century (Mowery, 1983) with the advent of the industrial research and development laboratories. These were considered to have made a major contribution to the growth of the large American and Germany chemical and electrical companies of that time. As a consequence, many studies have been made of the practical experiences of organisations selecting to manage technology in different ways in order to determine the significance of technology management upon the survival of the firm.

It seems clear from these studies that the competitiveness of firms and their more general welfare depend critically on the ability to keep up in innovative products and processes. Recent statistical studies show that the levels of companies' investments in technology explain international differences in productivity and in shares in world market (Fagerberg, 1987 and 1988). In addition, in the increasingly competitive and uncertain world since 1973, the rate of growth of business funded R & D activities in the OECD area has increased to such an extent that for some industries for example electronics, aircraft and fine chemicals, companies' expenditures on R & D are greater than their investments in fixed equipment and plant (OECD, 1983 and 1984).

Although these findings are based upon studies of manufacturing businesses, technological change is also effecting the way information intensive businesses compete, i.e. the banks and other paper based businesses in the service sector.

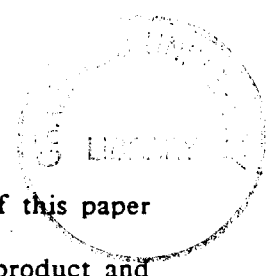
Unfortunately many UK technology-based businesses have not been able to retain the competitive advantage they once possessed and have lost market share or not survived. Two well known examples are the UK machine tool industry, and the UK computer manufacturing industry.

The causes of the demise of many well established UK technology-based businesses are complex and therefore, cannot be attributed to one particular management failing. However, the management of technology in support of the firm's business strategy must always have been fundamental to the development of a sustainable competitive advantage, in all technology-based organisations, if one accepts the findings of Fagerberg (1987 and 1988).

It is this management issue that is the subject of this paper. The strategic management of technology is however an issue about which there is considerable conceptual confusion although much has been published on this subject. Kantrow (1980) has suggested that:

"The major unfinished business of the research literature is to provide managers with needed guidance in their formulation of a technological strategy for their companies".

The aim of this paper is to present a conceptual model to facilitate managing the strategic contribution of technology to a company's competitive position. The ideas presented in this paper derive from the results of a study carried out in two UK manufacturing businesses, one in the electronics industry and the other in the mechanical engineering industry. The objective of the study has been to determine a methodology for technology management by examining the product development planning activities of the two firms during the last three years.



Although the study has concentrated on product development, the aim of this paper is to present a conceptual model for the strategic management of both product and process technology.

THE STRATEGIC MANAGEMENT OF TECHNOLOGY

To help with defining the task of managing technology strategically, De Meyer (1988) in a conference report on this management issue proposed that "the creation of a sustainable competitive position requires that we create a strong linkage between the company's business environment and the way the company develops and maintains its technological base".

De Meyer's view of the strategic management of technology is a limited one because it only describes one of the objectives for the strategic uses of technology, i.e. the creation of a sustainable competitive advantage. However, this is only one example of the use of technology as a competitive weapon. This study and other technological change studies (Steiner and Teixeira 1988) have observed that technological changes to products and processes have been made to defend a competitive position already established. The strategic technology management objective in this case is to exploit the opportunities created by technological change to destroy the competitive advantage gained by others. Changes made to the technologies used by the firm are the enabling agents for the firm to re-establish its competitive advantage.

An example of such a strategic use of technology would be the use of new technology to counteract a lower cost advantage gained by a competitor manufacturing in a lower labour cost location. Competitive advantage could be re-established by substituting labour intensive production operations by an alternative

technology, which was the Singer Sewing Machine Company's solution to its competitiveness problem when it developed the first electronically controlled domestic sewing machine.

Thus technology can be used strategically by a business to create and maintain competitive advantage within an already established business environment, i.e. its current markets. However, this is also a limited view of the strategic potential of the use of technology by a business. As Marone (1989) pointed out:

"But it is one thing to make technology decisions consistent with corporate strategy, and quite another to bring the potential opportunities that technology creates to bear on the formulation of corporate strategy. If the former is technology strategy, the latter is the strategic use of technology".

Much has been written on managing technology strategy but very little on the strategic use of technology, i.e. how technology can be used to shape the corporate strategy of the firm. The corporate culture required in the business to exploit technology strategically is an acceptance that the firm's technology could also be the rationale for a change in competitive position in a similar way to a marketing driven business that permits the marketing function to determine the specification of products to be developed and produced. Ansoff (1987) argues that firms should not be single but multifunctional in their business orientation.

To be able to effectively carryout the strategic management of technology will require those who are familiar with and participate in determining the strategic direction of the firm to be also familiar with the technological capabilities of the business. Thus there must be a close coupling (Ansoff 1967) between the company strategists and the management of the technological development function of the firm. This is shown in Figure 1.

DESIRED DIRECTIONS OF INFLUENCE TO DETERMINE
THE STRATEGIC DIRECTION OF A
TECHNOLOGY BASED BUSINESS

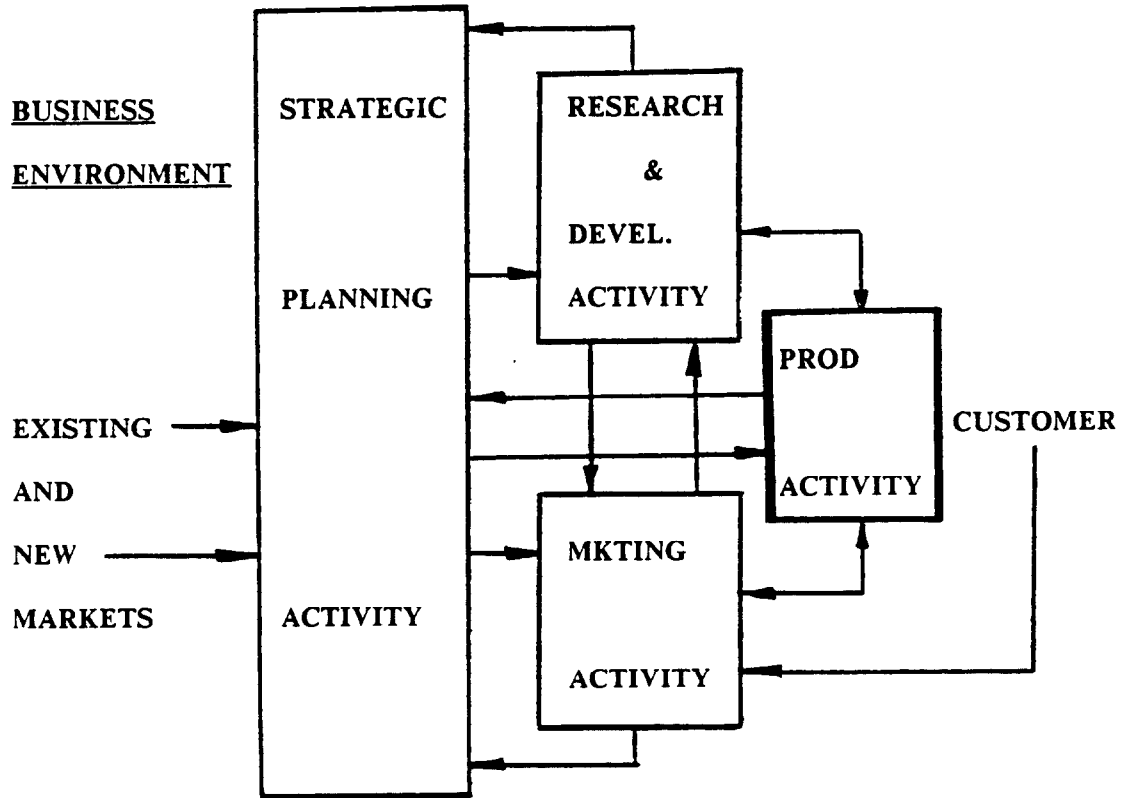


FIGURE 1

COUPLING DIAGRAM FOR A TECHNOLOGY BASED BUSINESS

Marone (1989) states that the two requirements for the successful strategic use of technology are a strong technological capability and the integration of the technology function into the strategic decision making activity.

Marone's analysis is consistent with the findings of this limited study. The two firms that collaborated with this study were created by entrepreneurs and both the founders have remained with the firms, one full-time and the other part-time. Their sizes are 250 employees with a turnover of approximately £40 million and 1250 employees with a turnover of £250 million.

Both founders of these firms are engineers, have strong personalities and drive and therefore, there has been a high degree of coupling between the strategic decision making body and the technology development function of the business. In both cases the founders headed the technology development function of the business.

However, as Marone has stated "Inasmuch as a technically trained CEO is more likely to have extensive interactions with the technical operation, technology is more likely to be integrated into strategic decision making. But the key factor is the integration, not the background of the CEO".

To develop a conceptual framework to facilitate the strategic management of technology, the model must therefore include the strategic options for an investment in technology to create new business opportunities for the firm. Such strategies would therefore be in addition to those technology strategy options appropriate to supporting the current market positioning and competitive strategy.

The model must therefore prompt an examination of how the acquisition of technology or the adaptation of the company's technological specialisation could

establish a competitive advantage in markets which are unfamiliar territory for the business. An example of such an approach is the Sony Walkman.

DETERMINING THE STRATEGIC USE OF TECHNOLOGY

Figure 2 shows a conceptual framework to facilitate the planning of a strategy for the use of technology for competitive advantage. Its design is based upon the need, detailed in the previous section of this paper, to incorporate the strategic options that are congruent with the current corporate strategy and market positioning of the firm and the use of technology to create new opportunities for the firm.

THE STRATEGIC OPTIONS FOR THE MANAGEMENT OF TECHNOLOGY

		<u>MARKETS</u>	
		EXISTING	NEW
<u>TECHNOLOGY</u> (PRODUCT OR PROCESS)	NEW (PACING)	TECHNOLOGICAL LEADER	PIONEER OR ACQUIRER
	EXISTING (KEY)	FEATURE DEVELOPER	PIONEERING ADAPTOR

FIGURE 2

The conceptual framework is designed upon the use of the Arthur D. Little (1981) categorisation of technologies, i.e. that technologies can be distinguished by their widely differing potential for competitive impact. Their competitive impact can be measured in two different ways, either through improved product performance leading to market advantages based on differentiation or improved manufacturing economics leading to cost advantages. These two results of successful innovation are not mutually exclusive and sometimes both are realised from product innovations. For example, the use of an electronic timing device in a washing machine, replacing an electromechanical unit, reduced the manufacturing cost of the product, increased the reliability of the device and simplified the manual assembly of the product.

Not all of the strategic options presented in the conceptual framework are feasible for all firms because limited resources, whether financial and/or technical may prohibit the adoption of certain strategies. For example, technological leadership may require an accumulation of technical competence in the technology where leadership is desired before the route to leadership is understood and attained.

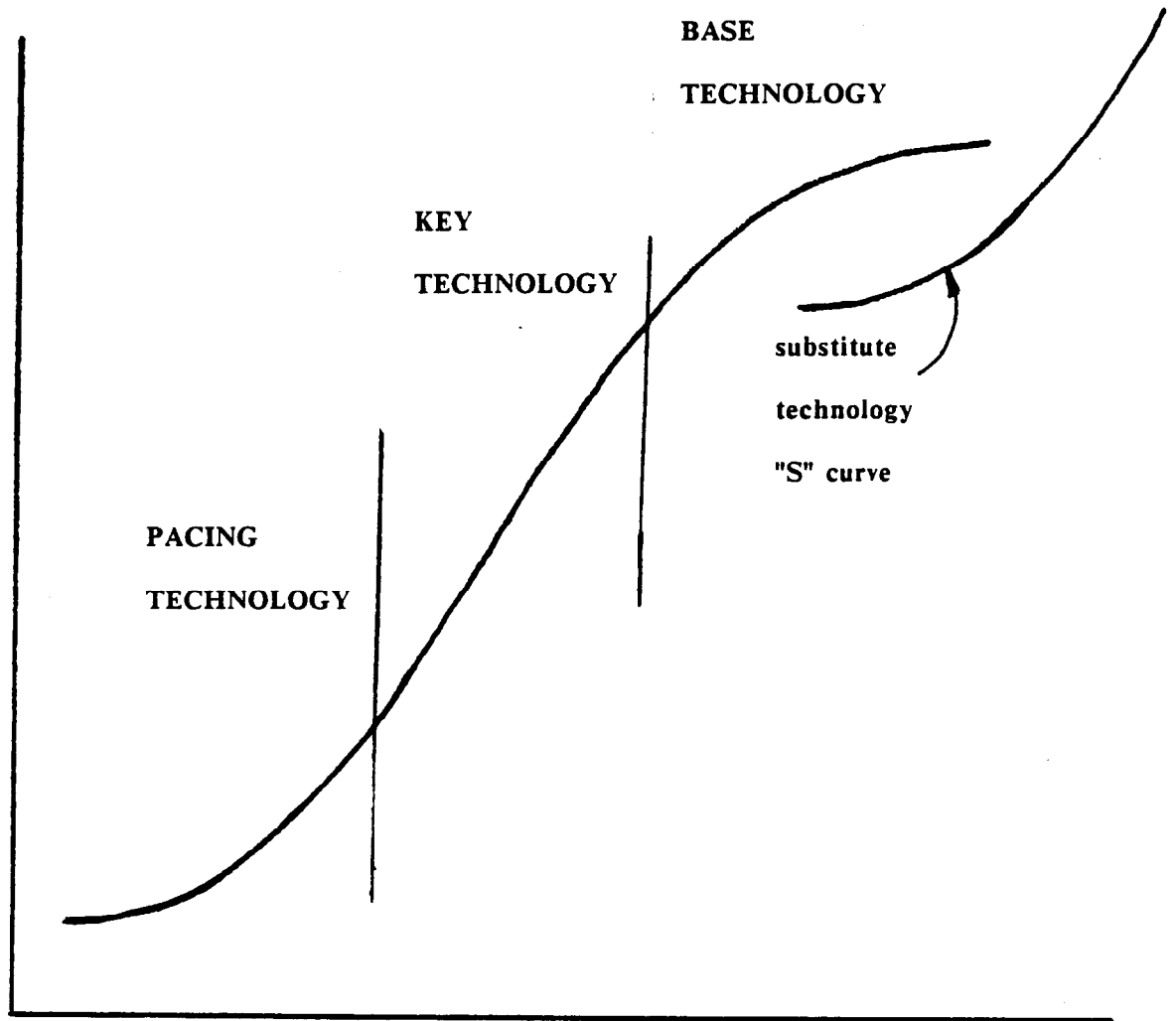
Therefore the selection of one of the strategic options shown in Figure 2 should only be made with a comprehensive understanding of necessary resources required to achieve the chosen strategic objective. The specifications of the required resources, detailed in this paper, are derived from the findings of this study and from other previously published empirical work on technology strategy which are listed in the references section of the paper. However, it is recognised that with such a small study it would be inappropriate to confidently specify that these specifications are complete. Further research is required on this resource specification issue.

THE CATEGORISATION OF TECHNOLOGIES

Figure 3 shows the evolution and discontinuity of technological development as described by Foster (1986). Along the "S" curve of improved performance is shown the categorisation of technology development as used in Figure 2. The strategic management of technology requires an estimation of the future potential of a technological change upon the current competitiveness of the company in order to determine the amount of investment the company should make to achieve the desired innovation.

THE "S" CURVE OF TECHNOLOGY DEVELOPMENT
AND THE CATEGORISATION OF ITS PROGRESS

PERFORMANCE
IMPROVEMENT



Management Effort
or Scale of
Investment

FIGURE 3

The terms pacing, key and base technologies are a means of defining the relationship between the stage in the development of a technology and its impact upon competitive performance.

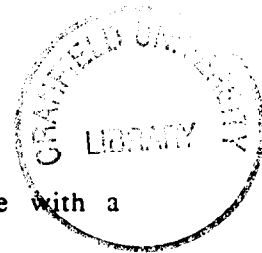
Arthur D. Little (1981) define these technologies as follows:

Base Technology: "We call a base technology one which is common to most industry participants of a business... it is no longer critical to the basis of competition, typically because it is widely available to all competitors".

Examples of base technologies are integrated circuit technology in the electronics industry and numerically controlled machine tools in the mechanical engineering industry.

Key Technology: "Technologies having the greatest impact on competitive performance at a particular time we call key technologies. To identify its key technologies, management must first review the market dynamics and competitive developments in its industry to determine its real basis of competition. Key technologies will be those with the highest impact on the relevant product performance or manufacturing economics needed to meet this basis of competition".

Examples of key technologies are manufacturing process technology for the volume assembly of complex products and the electronic technology for engine management in cars.



Pacing Technology: "Technologies in an early development stage with a demonstrated potential for changing the basis of competition we call pacing technologies."

Examples of pacing technologies are parallel processing technology and computer integrated manufacture.

COMPETITIVENESS AND THE CRUCIAL TECHNOLOGIES

Every product or operating system is composed of a number of distinct and identifiable technologies. The definition of technology, for the purpose of this paper, is the practical application of science to address a particular product or operating system need. Consequently all technology - based businesses deploy and manage a portfolio of technologies. The business management team should know the technologies that are crucial to the competitiveness of the firm i.e. those technologies that significantly effect the design and/or performance of the product or the operating system.

In addition, the interdependence of the crucial technologies should be understood, i.e. some technologies are relatively autonomous and their development can be independently implemented. Others may be dependent upon the technological improvements that are made to a critical part of the firm's main products or its operating system but the company may have no influence over the change rate of that technology.

The starting point for determining a technology strategy for competitive advantage is this basic understanding of the technological base of the firm.

DETERMINING A STRATEGY FOR THE MANAGEMENT OF TECHNOLOGY

The conclusion drawn from this extended study of the strategic management of technology is that there are only four distinct alternatives for determining the strategic use of technology for competitive advantage. These are shown on Figure 2.

TECHNOLOGICAL LEADER

This strategy is differentiated from the pioneer strategy because the goal is technological leadership in the current market and against existing competitors.

To adopt a technological leadership strategy entails the searching for and the development of the pacing technology of a critical technology for the firm. As a consequence, a "vision" of how to use a new technological development for commercial advantage must be shared by the senior management team or the "vision" must be an idea of the route to the discovery of the technological change that will substitute the current key technologies.

The barrier to the adoption of the technological leader strategy is what Ansoff (1987) describes as "strategic myopia". This is considered to be the cause of the demise of firms which have repeatedly missed the "new technology boat" and either lost their leadership or were forced to withdraw from the industry. The more successful the firm, the more likely it is to miss the boat!" Ansoff proffers an explanation why there is a high level of resistance to change in the successful firm, i.e. the approach adopted in the past may be counter-productive to the future because technological change requires a new approach to managing the technological base of the firm. This he describes as the obsolescence of the "success model".

For technological leadership there must be a commitment to both research and development. Consequently it is essential that the senior management team do not expect quick results when seeking radical technological change, the search may take in excess of five years (Quinn). A strategy for technological leadership requires sufficient financial resources for a continuous investment in research, the technological expertise to achieve technological breakthroughs and a longer term perspective of the return on research and development investment.

Technological leadership is a higher risk strategy than that of a product or process feature developer because there are greater uncertainties involved with trying to create a substitute technology than enhancing the performance of an established one. However, the rewards for developing the technology before the firm's competitors may also prove to be high. For example, consider the substantial cost and manufacturing lead time advantages that Mazak at Worcester has established through its development of its computer integrated manufacturing system providing the capability for the unmanned machining of components carried out during the night.

Technological leadership can result from accumulated technological competence developed over time through research successes and sometimes failure or by the creation of an entrepreneur who may have very little understanding of the commercial implications of the technological change.

FEATURE DEVELOPER

As the name for this strategy implies, this is predominantly a development intensive approach to innovation. This strategy is also the lowest risk one because it entails the development of key technologies to gain competitive advantage in existing markets.

All the well known product innovation strategies are types of the feature developer strategy, ie. fast follower and niche market product developer. In a similar way developing the key process technology to improve competitiveness is a feature developer strategy and is often complementary to product development.

This is an ideal technology strategy for the marketing lead business. Close coupling (Ansoff and Stewart 1967) is required in order to align the product innovations towards the specific needs of the customer. Much has been published on the financial and technological resource requirements of the feature developer, for example in Ansoff and Stewart, 1967.

PIONEER OR ACQUIRER

The third option for the strategic use of technology is the highest risk one and one of the two where technology could be used to shape the corporate strategy of the firm. The high risk is the result of choosing to seek and develop a pacing technology for exploitation in a new market.

The method used by many organisations to reduce the risk of adopting this strategy is to acquire the technology and the technological expertise through a takeover. A business may choose to adopt this strategy to create a new growth business when its current technological base is one of low growth and it is mature.

Another method of reducing the risk of implementing this technology strategy is a joint venture agreement to either share the risk of the research investment or to establish the product in the market.

This technology strategy is one of diversification of both the technological base of the business and its markets. The purpose of adopting this strategy is often to obtain

ownership of a technology that is perceived to complement the existing technologies of the firm and to exploit any synergistic benefits to be gained from its ownership.

An example of this high risk technology strategy is a camera manufacturer's development of a photocopying machine manufacturing business.

The resources required to implement this strategy are both technological and strategic. The technological expertise required is the early identification of an emerging technology as one with commercial potential and the ability to determine how some of the critical elements of that emerging technology complement the existing technological base of the firm.

The strategic perception required is to determine the strengths and weaknesses of the firm to determine whether a joint venture is appropriate and the customer needs of the new market to be entered. Financial resources will be required for the research and development of the pacing technology and for establishing the new market for the business. It is also obvious that, as with the technological leadership strategy, a visionary is a necessity and that strategic myopia would not be tolerated.

PIONEERING ADAPTOR

The aim of this technology strategy is to use the accumulated technological competencies of the firm to create new market opportunities for the business. It requires the identification of ways to develop key technologies in the firm in order to create new products for new markets. An example of the application of the pioneering adaptor strategy is the Sony Walkman.

The resources required for this strategy are again close coupling between the technologists and the marketing function. In particular it requires lateral thinking by the technologists and a good market intelligence organisation to record and evaluate customer suggestions and ideas for the enhancement or adaptation of existing products.

The resources required to implement this strategy are financial to pay for the development intensive innovations required to create the new products. In addition, further finances will be required to make the market aware of the innovations and establish a market demand.

The strategy is therefore more capital intensive than the feature developer strategy but such a strategy offers first to market benefits if successfully implemented.

The organisational requirements for a first to market strategy are also details in Ansoff and Stewart 1967.

CONCLUSIONS

The conceptual framework, presented in this paper, to facilitate the planning of a technology strategy for competitive advantage, is the result of limited study, anecdotal evidence and previously published research work.

The model is intended as a first attempt at providing a simplified overview of the alternatives for the strategic management of technology. Further research work may indicate that refinements to the model are required.

It is clear from previously published articles on this subject that the starting point for determining a technology strategy for competitive advantage is not to ask whether the strategy should be technological leader, first to market, fast follower or niche marketer. Each strategy requires different levels of investment and different types of technological expertise.

Therefore, the starting point should be an audit of the firm's resources. The strategy adopted, will, in the first instance, be determined largely by the firm's size, profitability and the nature of its accumulated technological competences. Perhaps the conceptual framework could then be used to help determine the future technology strategy of the firm with the knowledge of what kind of resources would be required to implement the chosen strategy.

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