PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

# Genesis of Advanced Materials-Based Market Products: Technico-Economic Aspects [and Discussion]

R. Malpas, G. Ellison and L. H. Schwartz

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# Genesis of advanced materials-based market products: technico-economic aspects

By R. Malpas, F.Eng.

*The British Petroleum Company plc, Britannic House, Moor Lane, London EC2Y 9BU, U.K.*

The future of technological development, and the importance that this has for economic prosperity, demands an improved flow of advanced materials from the laboratory to commercial reality. This process is too often hindered by high-investment requirement, long payback times, uncertainty, and hence perceived low returns and high risk. Overcoming the problem demands a reconsideration of the material-supplier–user relation, methods of business management and investment concepts.

Successful exploiters of advanced-materials technology need to address both short- and long-term markets and opportunities, which together will provide the required cumulative business growth and create 'options for the future'. This demands special management structures that ensure that the development and funding of products, technologies and markets are distinct from the day-to-day operations. It is also dependent upon the adoption of investment-valuation techniques that move away from traditional timescales to take account of the value of the new business options created, and the consequent profit potential in the long term.

## Introduction

Throughout history, the progress of civilization and the development of successive world economies have been inexorably linked with man's ability to harness and exploit the materials available to him. However, even after centuries of evolution and refinement in a trading environment, there is no such thing as a single definable industry that encompasses the range of materials that represent the very foundations of society. Instead, there is a highly fragmented assortment of materials businesses that overlap and influence the whole range of industries comprising today's national economies.

It is the development of these industries and the ever-increasing demands that their products are required to meet that has traditionally led to discovery and innovation in materials technology, and the consequent growth of materials markets. However, it should not be inferred that technological innovation occurs only in response to market pull. As Birchall (1983) points out in his paper, the course of history is often changed almost as a by-product of theoretically or experimentally inspired technological discovery, simply because the new material, for example polyethylene, or new effect phenomenon, for example Edison's lamp, or, more recently, the transistor, creates an opportunity for exploitation. Commercial success then depends on the ability to recognize long-term potential and link it to, or create, market demand.

Technology, market development, company structure, investment criteria and strategy all have a major role to play in advanced materials business growth. In this paper, I consider each of these, and address ways in which new, innovative developments can be encouraged towards commercial success by achieving widespread acceptance both within a corporate structure and in the market in general.

## The scope for technology

Historically, the timescale required for a material to move from initial innovation and development through to a stable – declining market is long, perhaps 20–40 years. However, all have traditionally followed the general growth–peaking, peaking–decline, decline–equilibration pattern shown in figure 1. On their way to the market place, most materials follow a consistent sequence of processing steps, as illustrated in figure 2. For mature or commodity businesses, the emphasis for success lies to the left of the diagram, that is ownership of, or proprietary access to, low cost resources and achieving economies of scale in primary processing. For new materials, particularly where the 'high-tech' label applies, the emphasis is on the right-hand side. Here, materials technology and production engineering skills, along with appropriate marketing expertise, are required to develop what are initially likely to be 'cautious', small-volume, high-value markets.

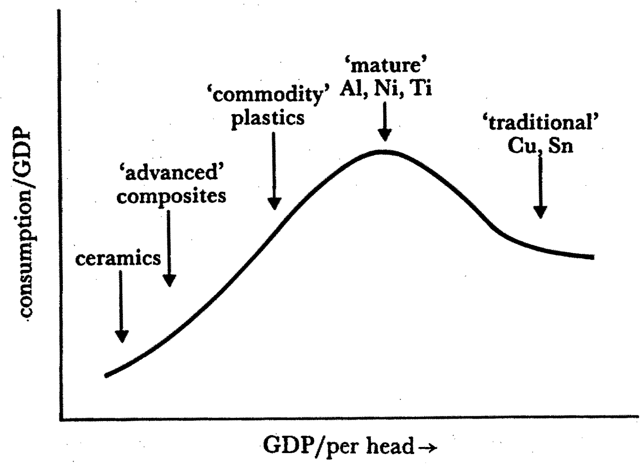


Figure 1. Materials usage.

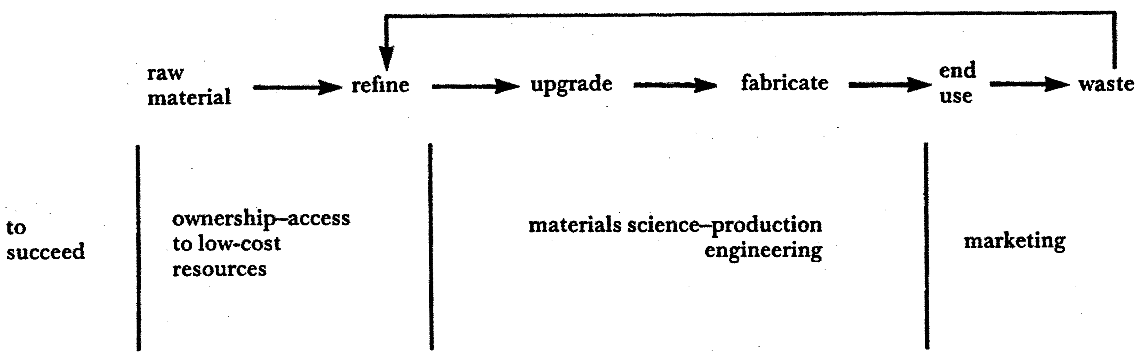


Figure 2. The materials cycle.

There are three necessary criteria for success in advanced-materials technology. The first is a fundamental scientific understanding of materials' structure–property relation, necessary to facilitate a considered judgement on the possibilities of, and potential for, a given line of materials development. The second is an integrated technical appreciation of the whole chain of steps, encompassing materials selection, design, fabrication and other factors influencing the acceptance of the final product either as a marketable item in its own right or as a component of some other structure. Of particular importance here is an appreciation of the influence that innovative processing can have on final product properties, and an ability to exploit this to ensure that the resultant materials are derived with optimum characteristics, net shape and cost. The third is an ability to coordinate technical resources to tailor materials to meet specific customer requirements.

All this must be underpinned by a conscious effort to educate tomorrow's designers and engineers to make optimum use of new materials for both current and future applications. These features are essential to the development of high quality, reproducible materials, which lead to increased user-confidence, which in turn increases the ability to design out the 'safety' factor, to realize the full potential of the material and hence to drive down the cost–experience curve (Boston Consulting Group 1970) to accelerate market growth.

The precise targeting of technical effort will, of course, depend on the area of proposed business and the prevailing level of associated technology. Although it is not possible to quantify with any degree of certainty, it is unlikely that a significant number of materials will be 'discovered' in the foreseeable future that can genuinely be referred to as *new*. Instead, the emphasis for technological development is likely to rest on better and more innovative use of materials that are already known and available.

In the context of engineering materials, this includes improved synthetic fibres, polymers, high-performance alloys, composites and ceramics, as well as thin films and coatings, and innovative combinations of these to gain synergistic performance benefits. The major technological barrier to bringing these advanced materials to the market, however, rests not so much on the ability to solve a problem or produce a test specimen in a laboratory, essential and praiseworthy though this unquestionably is, as with the development of viable products and their efficient commercial manufacture and exploitation. Consequently, there is a clear need, particularly in industry, and especially in this country, to concentrate effort on developing the design, processing and fabrication skills required to create a capability to manufacture products to a consistently high-quality level that satisfy the cost and demand constraints imposed by world markets. In particular, there is considerable scope for further work on such technologies as multiaxial filament winding, multidimensional weaving, rapid solidification, particle–powder consolidation, resin moulding and several others, with the emphasis on simultaneous processing of material and forming of the product so that the final shape and properties are obtained in one step. Application of clever chemistry and advanced control technology and automation are the key to such development.

The importance of addressing these issues more positively from a U.K. national viewpoint was dealt with in the Collyear report (Department of Trade and Industry 1985), which highlighted the significant role to be played by 'club'-type activities in several key areas. Successful development of new materials markets, however, depends on the willingness and ability of private industry, without government support, to allocate funds and resources which compete with other, shorter, time-frame needs.





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### Technology transfer: the relevant factors

The existence of a new material or process is merely the first step on the road to successful transfer to the market. In addition to a complete grasp of the technology, creation of a profitable new business in advanced materials requires a full understanding of the emerging industry structure, a well-planned strategy based on full awareness of in-house capabilities, recognition of the risks and constraints involved, and an acceptance of the need to adopt different concepts of management and investment values from those traditionally applied to established processing and manufacturing industries.

In the first place, a company needs to clarify a strategy as to what position it has or wishes to adopt in the materials industry based on its view of relative strengths and weaknesses. For a large company, with wide ranging resources, it might be pertinent to have a presence in several or all sectors from raw materials to engineered product, with the consequence that a development may be handled totally from within. At the other end of the scale, a company active in just one sector must be clear about the need to seek cooperation, license or to integrate forward or backwards to maximize the added value of its technology. Against this established position, it is possible to consider the risks and constraints associated with future market development.

Any new technology carries with it some risk in the commercialization phase, and this is accepted as part of the process of evolution. Maximum technical risk exists for a new material in a new application, as exemplified perhaps by the failure of Rolls Royce's development of carbon-fibre turbine blades. Although this combination can succeed for a needed novel application, like new photovoltaic materials for remote site power generation, most developments are likely to be in lower risk situations, where the new material is introduced as a replacement in an existing application.

Financially, the risks increase exponentially as we move through the progression chain towards application. Those facing an aircraft manufacturer, for example, are significantly greater than those facing the developer of composite tailplane components. This factor is understandably one of those most instrumental in slowing down rates of acceptance of new materials in industry.

The successful introduction of a new material to the market is also subject to a number of constraints, particularly when embarking on the early stages of a high-technology business. To begin with, there is a strong likelihood that the new material or process will be replacing another than has a good track record. Unless there is a known problem with the existing material or a major cost or proven performance advantage with the new one, there is likely to be reluctance to change. Furthermore, there is the possibility that the existing technology will be upgraded in reaction to the new threat, as we are now witnessing in the aluminium industry's development of aluminium–lithium alloys, and superplastic forming of titanium in the aircraft industry, to combat the swing towards fibre reinforced composites. Current lower energy costs will be helping them in this respect.

Then there is the constraint imposed by user's capital equipment and cost. Not only is capital cost itself a deterrent, but there is also pressure, particularly in those companies with fewer resources, to ensure that the new materials and processes are compatible with existing equipment. Finally, there are the legislative constraints associated with meeting performance and environmental standards, and the less tangible one of gaining user confidence. In some cases, the absence of agreed legislative standards for new materials further inhibits successful technology transfer, as it erodes user confidence.

## The way to the market

Because of the factors just outlined, and the fact that new materials are generally used by properly conservative engineers whose confidence in the material needs to be built up, the time lag from innovation to mature business is usually long. In consequence, long-term success in the market requires a high level of commitment, patience and an ongoing perception of technological and commercial needs beyond the next development. For the materials supplier, two factors in particular are essential for successful commercialization.

The first is the early establishment of a market presence. In many cases, this will already pertain, but for companies new to an area, the possession of the best technology with the greatest market attraction is useless if access to that market and a working knowledge of its requirements and characteristics are restricted. Furthermore, such a market presence fulfills the essential role of a 'barometer' to assist in forecasting future requirements and markets, an essential feature for long-term business growth.

By way of example, BP has adopted this strategy for its developing photovoltaics business, establishing a business presence ahead of the emerging technological position. Over recent years, BP Solar International Ltd has established production and marketing facilities in several countries by using state-of-the-art technology to move more rapidly down the learning curve and gain a working appreciation of the commercial and technical aspects of the business. We are finding market niches that now require the performance of this type of product (that is, remote sites) rather than substitution, where it cannot yet compete. From this position, the company is able to take advantage of new technology, systems and marketing strategies now being developed, which will significantly improve cost performance in the early 1990s and hence broaden the applicability.

The second factor for success is an identifiable application for the material or process in question which:

(*a*) demonstrates a clear cost and/or performance benefit over alternatives;
(*b*) has an obvious 'market pull' and sufficient potential market size;
(*c*) stands up to the constraints outlined in the previous section.

The role of obvious market pull is particularly important. There are many examples, including memory metals and (until recently) carbon fibres, where good technical developments have found it hard to find that initial application which leads to the development of robust market opportunities so necessary to fulfil commercial potential.

The benefits of the innovation must, of course, also be perceived by the user and eventual customer. Often, particularly where the innovation or new material is intended to be a component of some other final product (e.g. ceramic glow plug or diesel engine combustion chamber), joint development, with each partner fully accepting its share of both the risks and the commitment to eventual purchase and supply, can be an attractive way forward. Indeed, cooperation and joint ventures of this type between materials suppliers and equipment manufacturers are now the norm in the aerospace and defence industries. In other industries, cooperative involvement often depends on finding a suitable test application in the high value or speciality sector of the end-user market, where initial high costs can be sustained, for example, racing cars for the automotive industry.

The establishment of a consortium comprising raw-material supplier, component manufacturer and end customer, such as tends to be favoured in the U.S.A., is an effective way of developing the business potential of each stage of the chain without risk of loss of technology to a competitor. The U.S. Department of Energy sponsored 'Ceramics Applications in Turbine Engines' (CATE) programme spearheaded by General Motors is an example. The drive that this imparts to progressing to successful commercialization and mutual benefit is greater than that associated with the 'club' approach.

Care should be taken at this early stage, however, not to invest immediately in ambitious production capacity, sufficient to satisfy the supplier's perceived long-term market, in an attempt to achieve economies of scale. A smaller plant, installed at lower cost, carries a lower overall risk, maximizes efficient operation through higher use factors during the market development phase, and throws up the shortcomings that inevitably arise with any new process. Due account can then be taken of these when developing the next stage. However, the next stage must happen and it must not be left to others to reap the real harvest, as has so often been the case for the U.K.

## The 'technology after next' concept

The identification of the first commercially viable application for a new material, and the move towards its exploitation, is little more than putting a foot on the first rung of the ladder for an advanced-materials business. It alone is seldom likely to develop into a significant *business* within a timescale that will excite corporate management and instil confidence for future growth potential. Few companies would wish to embark on this first stage without the potential for a substantial business in the long term. It is therefore at the point of decision on the first application that the company, particularly its materials designers and engineers, must also look ahead to assess the needs and opportunities of the next. That is, it is necessary to adopt a policy of innovative foresight, close liaison with end users, and patience. It is a game of developing options for the future, a phrase I shall use frequently.

BP's involvement with composite materials offers an illustration of this principle. Although not directly associated with their manufacture, BP's understanding of composite pipe technology, gained as a result of North-Sea operations, was directed towards developing composite materials and components for other in-house uses and new business development. The first two of these were a strong, lightweight LPG (liquified petroleum gas) vessel and a novel epoxy prepreg system. These developments have now opened up further new business options by extending the technology, both in-house and through close liaison with universities, subcontractors and end users to a variety of other products with applications across a range of industries. The options for the future involve other technologies, other products, other markets.

This lateral-thinking approach does not rely on the initial application being a major commercial success, particularly as it probably has to carry the major share of any developmental and certification or approval costs. Even allowing for the fact that a proportion of the envisaged markets will not materialize, or applications will not in some other way succeed, the ability to adopt and develop a generic technology base with sufficient long-term options will help ensure adequate business growth for the innovative company.

## Financial implications and management

The approach advocated in the previous section is fine provided that it can be financed and managed properly. The implied commitment to R & D in the proposed approach, which may be of the order of 10% of turnover of that business sector, is clearly greater than many smaller companies would wish or be able to finance if funding is available only from ongoing business income. Development under these circumstances must of necessity depend more on venture capital, government contract or research funding (historically less forthcoming in the U.K. than it is for international competitors), or club–consortium financing. In the U.S.A., government contracts represent a major source of income for several advanced materials companies, both large and small.

It is not my intention in this paper to discuss in depth the mechanisms available for developing advanced materials businesses within smaller, independent companies. Nevertheless, it is in small companies that many of the new, innovative developments are initiated, and it is important to ensure that there is funding available for the most promising. A healthy advanced materials industry will therefore need both small and large companies to provide growth. Larger companies, with their capability for allocating funds and resources for both technology and business development over the longer term, have a particular role to play. It is a 'proper' use of the financial and R & D strength of large companies, and it is on the management of such activities within a large company that I shall concentrate for the remainder of this paper.

The availability of cash, human and R & D resources is by no means a guarantee that a larger company will be able to succeed in developing advanced materials and market them successfully. Large companies have to overcome the problem of 'unfamiliarity', that is a reluctance to meddle in unknown new business areas, as opposed to greater corporate comfort when 'sticking to the knitting'. However, a realization that the knitting might be a declining activity does provide an incentive to try something new. Nippon Steel's involvement with silicon carbide (Fellowship of Engineering 1983) is one such example, not to mention what oil companies might currently be thinking!

Several problems exist in attempting to grow businesses from within a large company. There is only time to deal with a few. Firstly, unless the new business is virtually a continuation of the company's mainstream activity, there is every likelihood that it will demand a different style. No amount of juggling with the figures and timescales will enable the parameters of the new activity to be adapted to fit those of the mainline company business, with the result that there is always a residue of discomfort within the corporate body not used to playing under the rules of the new game, if any. Secondly, the imposition of parent company overheads on a venture of this type, which is already unlikely to show an impressive short-term return, is virtually guaranteed to destroy any hope of success. Thirdly, there is often a problem of identifying the line of responsibility for the venture within a large company. If several streams are involved, for example through transfer of different technologies or by fitting the development into one or more of the existing business streams, conflict of direction and management will arise, and chances of success of the project will be depressed by its lack of materiality. Finally, there is always the temptation to concentrate *all* the corporate resources, for which there is invariably fierce competition, on evolutionary developments in established businesses that provide substantial short–medium-term rewards, rather than take a risk in a new area of advanced materials, where the promise is long term.

As a consequence of these factors, there is an overriding need to find a way of justifying medium to long term developments in new business areas – which can represent a threat to the *status quo* – in a quantitative manner. A suggested approach to this is given later. Another essential feature, however, is to ensure that the new material business activity is kept separate from the corporate body, drawing on the parent only for support as necessary.

To deal with this situation, we in BP have adopted two organizational arrangements (figure 3). BP Ventures is established as one of our eleven business streams, charged with growing businesses that do not readily fit into the other ten more established activities. The genesis of BP Ventures businesses is generally, but not exclusively, technology that emanates from our R & D activity. BP Ventures is therefore both the champion of, and the insulator from, the corporate hand: heavy necessarily to deal with large established businesses but deathly if allowed to fall on tender flowers.

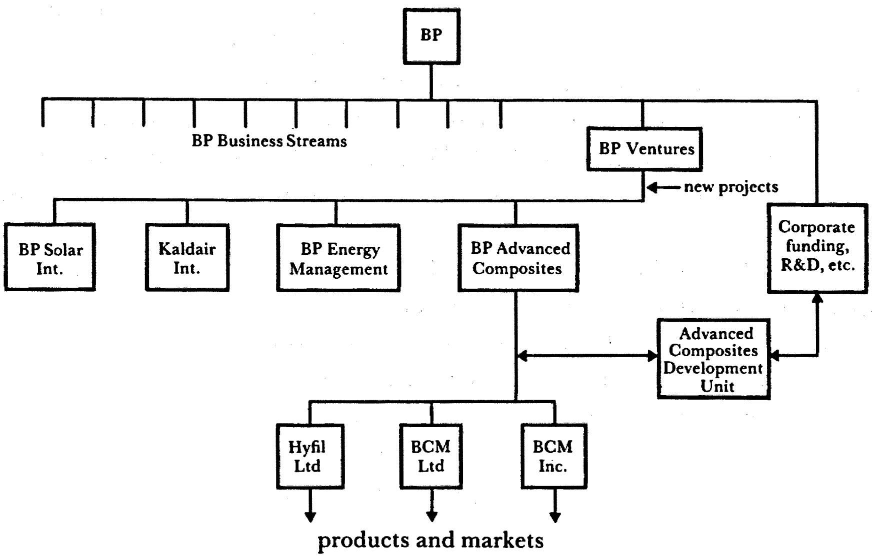



FIGURE 3. Management structure.

Within BP Ventures we have several small companies trading successfully, but even they are still tender and need nurturing to grow. For any new development, we seek, if possible, to attach it to one of the Ventures companies to give it a 'home' where it can be weaned. However, the attachment is such that it is not allowed to cause the small parent to be distracted from developing its own business profitably. Thus we finance the new development corporately (through Ventures) and form a development team, including seconded R & D people, separate from the venture company's mainstream activity.

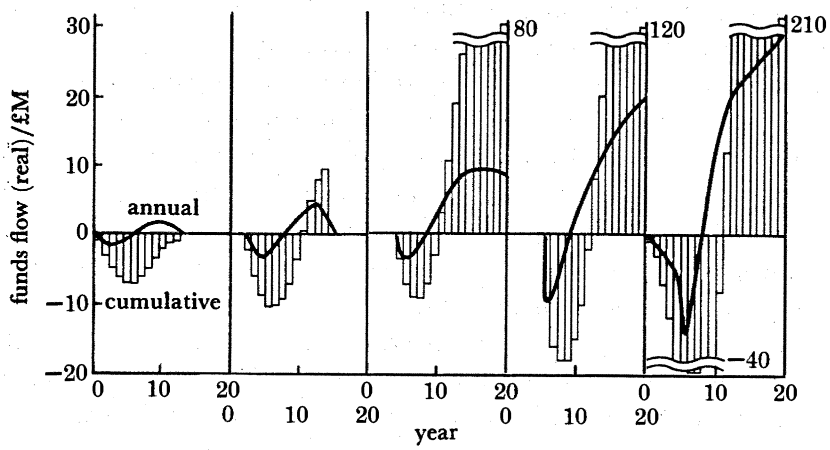
The use of 'hooks' of this kind provides a real bridge between the laboratory prototype and the realities of product development, production engineering and marketing. This is obtained from being alongside a real, though small and usually struggling, business that is further along the road towards substantial commercial success.

## Investment

The foregoing sections presuppose a strategic commitment within the management of the company to a new business development that will bring long- rather than short-term benefits. How, though, is this to be achieved when such commitment has to be justified against the yardsticks (or rather timescales) generally prevalent in private industry?

To begin with, it is important to acknowledge the principle that a higher charge against the present is necessary to ensure a long-term future. Failure to commit to new technology, plant and/or R & D, over and above that needed to maintain ongoing operations and facilities, will eventually result in an increase in average age and consequent decrease in value of company assets.

Acceptance of this principle is essential for new business growth in advanced materials. Given that the corporation has embraced the objective that a new materials development is in line with corporate strategy (more likely to be accepted for a diversification activity if there is some connection, however tenuous, with existing company strengths), acceptance and approval by all but the most committed of managements depends on the adoption of a method of evaluating investments that takes into account the long time scale involved. Such a method, however, does not require the introduction of new, unfamiliar parameters, merely the adoption of an enlightened approach to the use of traditional ones.




| | 1 project | 2 project | 3 project | 4 project | total business |
|---|---|---|---|---|---|
| DCF$_{10}$† | negative | 7 | 28 | 20 | negative |
| DCF$_{20}$ | — | — | — | — | 20 |
| NPV$_{10}$‡ | −3 | −1 | 7.5 | 7 | — |
| NPV$_{20}$ | −2.5 | 0 | 15.5 | 19 | 32 |

† DCF$_x$ is the percentage cash flow rate of return for $x = 10$ years or $x = 20$ years.

‡ NPV$_y$ is the net present value in millions of pounds sterling for $y = 10$ years or $y = 20$ years (discount rate used is $-10\%$).

Figure 4. New business funds flow.

Consider a new advanced materials business venture growing by a positive strategy of investment over a long period as described by the funds flow of the simple model in figure 4. Projects 1 and 2 represent relatively small scale investments, leading to 'development' markets based on a generic technology, perceived to have technical and commercial stretch for the future, exploited in projects 3 and 4. Projects 1 and 2 have poor discounted cash-flow rates of return over the first ten years of project life, with cumulative cash flow, regarded by most people as an immediate indicator of project viability, showing infinite or long pay-back periods, reflected in that of twelve years for the total project 1 business. Furthermore, the net present values (NPV) of these two projects, which must be calculated using a high discount rate of, say, 10% per year to reflect adequately the risk inherent in the early stages of the venture, are negative. Neither project would therefore justify its initial investment when judged conventionally.

To reject them at the outset, however, places too much emphasis on the present and ignores the foundations which these projects lay to create new business and options for the future. Both projects, particularly the first, are small, so apparently of little consequence to a large company, and they show very poor financial returns. However, low materiality, with its associated low costs, can be regarded as a desirable feature for a project of poor viability in a high-risk market like advanced materials, because it can provide a relatively cheap entry route, essential to getting on to the learning curve. If you are not in the business, you cannot drive it down the learning curve. Learning here embraces the technology of the product, the process to make it and, particularly, knowledge of the markets, and how to market the product. The ultimate markets are frequently significantly different from those envisaged at the outset.

The comparatively low cost financial 'failure' of such initial projects in materialistic terms is really of small consequence in the long run if they provide a basis for comfort and informed subsequent investment in more profitable projects to accelerate growth, such as projects 3 and 4. These aim for bigger businesses through acquisition or more significant plant and market investment and, although they require higher levels of development and capital funding, they show more attractive return rates, discounted cash flows (DCFS) and NPVS as a consequence of the experience gained from 1 and 2. Neither the subsequent projects 3 and 4 nor an acquisition are likely to be embarked upon with confidence without the experience and knowledge acquired through the first two, which provide the 'comfort factor'. They represent an 'entry fee' launched to develop major 'options for the future'.

Judgement of financial viability for new long-term growth businesses must not therefore be made on conventional timescales. To do so is rather like designing a high-performance car and then road testing it only in first gear, because it takes no account of the value of subsequent growth investments that give the activity another dimension and buy significant new business *renewal* options. Despite the poor showing of projects 1 and 2 in the early stages, the whole new business taken over a longer, twenty year, timescale so as to recognize the value of these options shows attractive return rates, DCFS and NPVS, the latter being the arithmetical sum of the individual project NPVS over the full period. Funds sunk in projects 1 and 2 are therefore the necessary costs of launching the new business, and it is money well spent. By year 8 in the example, when annual funds flow eventually becomes positive, the cumulative 'patient' money investment (NPV at year 8 inflated at the discount rate) is £55 M: a low entry fee for a business by then worth £100 M based on the next ten years discounted funds flows!

Obviously there are enormous risks, but no new, significant business was ever developed

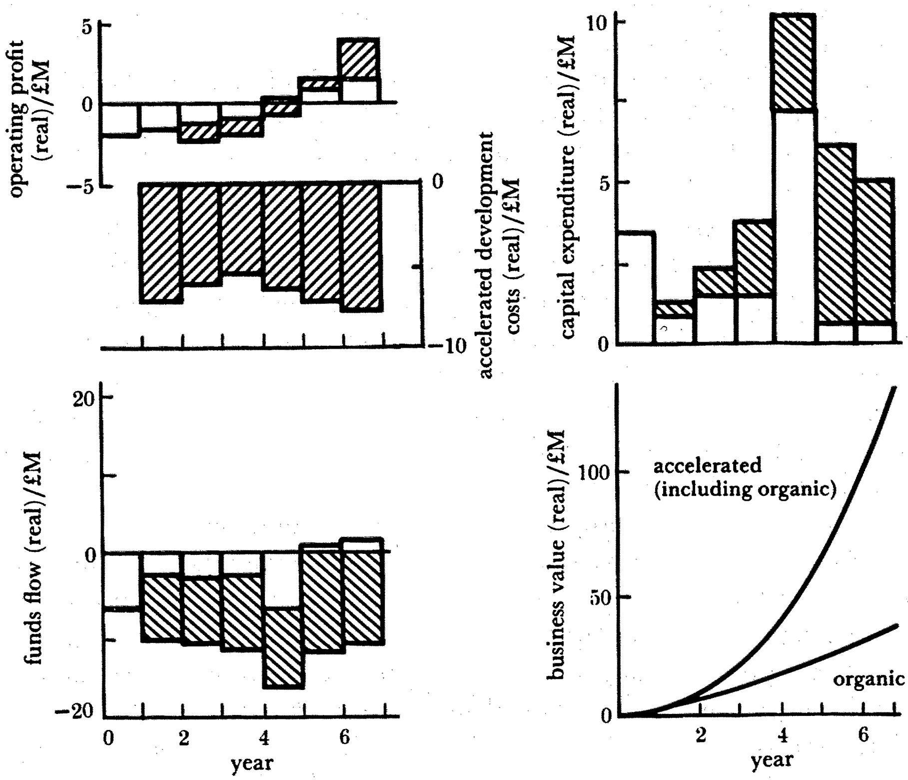



Figure 5. Development funding and business value. Open columns, organic; hatched, accelerated.

otherwise. The point of this presentation is to show quantitatively how eventually the venture can win, and show it in terms familiar to those whose timescales of assessment are more short term.

The advantage of patient money investment strategy to facilitate *accelerated* new business development in a growth industry can be more clearly seen when compared with the alternative of organic growth against lower investment. Figure 5(*a*–*c*) reflects a recent materials-related real case within BP. Organic growth is expected to return small, positive operating profits from year 5, with positive funds flow, after allowance for capital expenditure, in year 6, that is within a reasonable and generally acceptable timescale. All very respectable, but hardly indicative of a substantial new business. The alternative is the adoption of an accelerated growth strategy, whereby significant extra capital and, particularly, development funding is needed to buy, by investment or acquisition, a more substantial business position more rapidly, as shown. The relative magnitude of this developmental funding (figure 5*a*), which includes a large slice for vital market development so often forgotten by British companies, will severely depress the funds flows of the growing business.

Vindication of the accelerated growth tactic lies in the market value of the business that is being built up: that is, its value if sold to others (figure 5*d*). Left to organic growth, the business would be expected to achieve a value of about £30 M by year 7, based on expected funds flow, but there is a good chance that it will, by then, have been overtaken by competition, though it could probably be sold at a profit. The extra patient money invested, however, amounting to about £75 M (NPV of cumulative 'accelerated' funds flow at year 7) has, hopefully, turned the business into a major springboard for the future, with much greater potential, and a market value, based on anticipated profits and a high price/earnings ($P/E$) ratio† typical of rapidly developing businesses in expanding industries, of £120 M. This is not only £90 M higher than the organic case, but reflects the alternative price of entry should the company delay involvement in favour of buying in later, without experience, probably at the high point of its $P/E$ ratio valuation.

It is quite legitimate to use business valuation as a method of assessing financial reward, particularly before a venture has earned any profit, or when the profit earned is still low compared with its potential. After all, many companies are bought for large sums when profits are low or negative because of the recognition that they have established a technology, product or market, hopefully all three, and hence paid the entry fee. The recent composites acquisitions of Narmco, Fiberite and Union Carbide (fibres) by BASF, ICI and Amoco, respectively, and that of Hybritech by Eli Lilly in the biotechnology field are examples, but there are plenty of others we can all quote. The acquiring companies have all bought options for a future that they perceive to be significantly greater than if they had not done so.

Thus it is perfectly justified for a venture manager to quote a market valuation as a means of quantifying the fruits of the initial years' hard labour if such a valuation can be assessed. For example, we bought a company for £3 M in 1979 and, though it is highly profitable, the absolute value of that profit is today less than £1 M per year. We have been approached to sell it. We will not, but even if we did, we would only entertain bids above £30 M. Taking credit for what we have added to the market value of that business is a legitimate way of justifying the enterprise. The tradeable value of an enterprise is just as legitimate a method of measuring human endeavour as is the value of the goods and services currently produced.

It may be argued that these methods of presentation are obvious, and that managements, financiers and analysts automatically take them into account when judging results. They are indeed obvious, but certainly they are not taken into account unless specifically articulated and presented. I offer them as an aid, a tool, to those whose endeavours are otherwise undervalued and the potential of their efforts not seen. They are also useful to cause new venture managers to have to articulate more clearly *why* they want the corporation – or investor such as a venture capitalist – to invest patient money. The answer 'for strategic reasons' will no longer do. The vision, both qualitative and quantitative, however tentative, needs to be articulated by setting out possible options for the future that will result from the patient money, so-called 'strategic' investment. I have found the 'options for the future' challenge powerful both when applied to those who seek resources, and to help persuade my colleagues that a patient money venture is worthwhile.

Naturally, a company can only afford a limited number of patient money projects. Cash flow is needed today, otherwise there will be no tomorrow. Conversely, without cash demanding projects today there will be a poorer tomorrow. 'A proper balance' is the answer.

Some years ago I coined the phrase 'DCF is the enemy of strategy', concerned that heavy discounting, particularly in times of high inflation, makes earnings in the later years of a project seem valueless. I am not usually given to negative comment, so determined to develop a

† This is the ratio of the value (as measured by the stock market or potential buyers) to its earnings after tax. (For companies quoted on the Stock Exchange $P/E$ ratios are shown daily.)





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methodology, by adapting the 'number crunchers'' own techniques, that could illustrate the financial benefits of long lead time ventures.

I have described the small armoury of techniques that I have devised and collected over the past few years. They are essentially based on three points.

(i) The simple arithmetical fact that the NPV of a discreet project is unaffected by time. That is, if a first project has an NPV say of minus £10 M and a second, consequent upon the first, an NPV of £100 M, then regardless of the time lapse between the two, the aggregate NPV of the two is £90 M.

It is evident how this principle has been used in the example given.

(ii) The concept of generating 'options for the future', which is very powerful both qualitatively and, by embracing the first point, quantitatively. I am indebted to Professor H. Jacobi of MIT who, in personal discussion with me, articulated the concept, for it has allowed the withdrawal of the phrase 'for strategic reasons'. Instead, the possible options – technological, product, market, geographical, etc. – have to be enunciated, however tentatively. The vision, the possible options, have to be described.

(iii) The use of business market valuation in a venture properly to reflect the value of what has been created so far. There is a market for buying and selling embryo businesses. It is a market that values expectation. It is perfectly legitimate to use this for internal measurement of achievement.

The U.K. has traditionally not been short of embryo technological innovations. It is therefore time to promote methods of assessing risk and long-term reward that will enable them to be exploited more profitably in the future.

I am endebted to my colleagues at BP, Mr P. D. Histon and Dr P. G. Faulkner, for their efforts in helping me to prepare this paper. They did most of the work.

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## *Discussion*

G. Ellison (*Department of Mechanical Engineering, University of Bristol, U.K.*). I was most interested in Dr Malpas's paper on the economic aspects of new, possibly speculative, work carried out in a company. My question is more directed at this problem in the context of the U.K. rather than a single company.

Though the U.K. may still be relatively rich it seems to me to be on a declining path in terms of wealth creation. Undoubtedly we are good at research innovation and invention but we do not always sustain this to a profitable end.

Is there any evidence that we are spending our research monies in the best way to give this nation the best return in terms of a profitable future? I presume a successful company such as BP must analyse its needs in this way; does the U.K.?

R. Malpas. BP certainly does have profitable exploitation of its R & D as its prime objective. It is indeed difficult, even so, to commercialize technology beyond the prototype stage. We devote considerable effort to do so. Not every promising start, or attractive prototype will succeed commercially. Acceptance that there will be failures is an important feature to inculcate throughout management; however, this is not easy to do.

Nationally, I think we are making real progress in harnessing our R & D to better effect, but there is still a long way to go.

L. H. Schwartz (*Institute for Materials Science and Engineering, National Bureau of Standards, U.S.A.*). Dr Malpas, in his discussion of the organizational structure of BP Ventures, did not address the issue of incentives. We commonly find in the U.S.A. that because managers change jobs frequently they expect to be judged on the basis of short-term performance, and that this typically leads to decisions favouring short-term profits instead of long-term growth. Would he comment on how the BP Ventures organization rewards managers who dare to be far-sighted?

R. Malpas. BP Ventures has the difficult task of creating new small businesses and growing them successfully such that they provide a springboard to large businesses. This cannot be done without taking a long-term view of the future, and at the same time demonstrating, in the early stages, that there is a profitable business to be built. This difficult task of demonstrating profit in the short term but building for a long-term future is the mission of every one in BP Ventures. That ability is what the Board of BP Ventures expects of all the executives, who are rewarded accordingly.