LECTURE 8 25 March 1988

STRATEGIC ASPECTS OF R & D MANAGEMENT*

1. Corporate Planning

Corporate analysis and planning involves a systematic examination and integration of several inter-related elements such as corporation, goals, environment, analysis, planning, strategy, policy, policy agent, policy instrument and implementation.

A corporation in the general sense is the entity/body/agency/institution for which planning is being carried out.

A goal is a specific medium- to long-term objective -- it is the end-point to be achieved. Corporate goals must be specific so that, in the case of a firm for example, there must be a definition of products and markets with quantified targets related to a specified timetable for the achievment of market shares, turnover, profit, etc. Thus, not only the end-point to be reached (i.e., where the corporation should go) but also at what time the goal should be reached (i.e., when the corporation should reach the goal) must be specified.

Analysis involves a study of the strengths and weaknesses of the corporation (i.e., what the corporation can do), and of the opportunities and threats in the environment (i.e., what the corporation might do considering the dangers it faces) -- the process is often referred to as SWOT analysis. Analysis also requires a monitoring of implementation.

A strategy is a path for reaching the objective -- it is a broad plan to reach the goal. The chosen strategy must depend on the strengths, weaknesses, opportunities and threats, i.e., it must depend on the outcome of the SWOT analysis.

Planning consists of the selection of a corporate strategy (i.e., how to reach the goal) on the basis of a consideration of alternative strategies. In the case of firm-level planning, the alternative strategies for products could include (1) producing more and marketing more, (2) reducing manufacturing costs, (3) vertical integration of the various steps in production and marketing for the same volume of output, (4) enlarging the product range and the market. Other alternative strategies could include new markets or the acquisition of new companies through mergers and acquisitions.

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* This lecture has drawn heavily from the chapter on Strategies for Research and Development from the book by Brian C. Twiss on MANAGING TECHNOLOGICAL INNOVATION

A policy is a specific and concrete course of action to implement the strategy. Thus, goals, strategies and policies constitute a heirarchy in which as one proceeds from goals to strategies to policies the focus becomes sharper and sharper. The course of action involved in a policy requires, on the one hand, a policy instrument to initiate and maintain the policy, and on the other hand, a policy agent to wield the policy instrument. And, implementation of the plans, strategies and policies involves the translation of ideas and intentions into actions in the real world.

The inter-relationship between the elements of corporate analysis and planning can be brought out through a systems diagram (Figure 8.1). The diagram shows that strategy formulation must be an iterative process.

Corporate planning depends upon R & D because R & D can come up with (1) new products and (2) new manufacturing techniques (a) to increase productivity and/or (b) to decrease costs. R & D may also identify new threats and opportunities of which the corporation would otherwise have been unaware.

It follows that R & D planning must be incorporated into the corporate planning process. But, the outcome of R & D is not certain and therefore how does one plan the unplannable? How does one allow for the chance element in R & D?

2. R & D as a Business

There is a fundamental difference between managing the non-routine creative process of R & D and the routine operations of a factory -- in R & D, even the managers do not know the precise answer beforehand (in fact, the purpose of R & D is to find answers) whereas in a factory, managers can give precise instructions. Thus, in the management of R & D, managers have to depend upon the creativity of those whom they are managing. And creativity requires an environment of freedom for it to fructify. At the same time, there is the necessity of moving towards the goals of the organization.

One way of making the freedom of the participants in R & D compatible with corporate goals is by transforming R & D into a side-business that is distinct from the main business of the corporate entity (Figure 8.2). The approach is as follows.

Normally, the corporation not only transmits to its R & D organization its corporate needs but also provides funds for R & D. The corporation can insist that the bulk (say 90%) of these funds are strictly committed to projects that are related to corporate needs. But, there can be a small fraction of these funds (say 10%) which is left to the discretion of the R & D organization to spend on projects of its own choosing even if these are not apparently related with corporate goals. Within the R & D organization, scientists and engineers canm be

permitted to spend about 10% of their time on personal research even if it is unrelated to corporate goals. Through this approach, several results can be achieved. Firstly, an R & D organization can devote about 10% of the funds and time to "free projects" not directly linked to corporate goals. Secondly, the scientists and engineers feel that their desire to pursue topics that interest them is not curtailed. Thirdly, provision has been made for serendipity, i.e., the important faculty of making unexpected discoveries by accident.

The planned "corporate" and unplanned "free" projects in such set-up fall into different categories depending upon the outcome of the R & D (Figure 8.2):

(1) a certain number of planned and unplanned projects (11, 12, D, E) turn out to be failures and will not yield any commercial value;
(2) many "corporate" projects (1-10) advance corporate goals:
(3) some unplanned projects (X, A) end up as contributing to corporate needs;
(4) other unplanned projects (Y, B) produce results that necessitate the modification of corporate goals;
(5) a category of unplanned "free" projects (Z, C) turn out to be successes and commercially exploitable even though the resulting technologies are not connected with corporate goals.

The categories (2), (3) and (4) advance corporate objectives and directly justify its investments on R & D -- they promote the main business of the corporation. In addition, if the technologies from the last category of projects are licensed or sold or patented and the patents leased, then the sale of technology from unplanned "free" projects can become a lucrative side-business.

Thus, a corporation with R & D activity is really in two businesses -- a main business defined by corporate goals and directed towards satisfaction of identified market needs, and a side-business in which it generates and sells technologies of commercial value. This two-business approach combines serendipity and personal research with corporate work and also permits freedom to be consistent with corporate goals.

3. R & D strategy as a Component of Corporate Strategy

Though a consciously evolved R & D strategy requires a considerable amount of effort, four reasons can be advanced for believing that the resulting advantages are worth the effort. Firstly, profit maximization is inadequate as a goal; secondly, forward planning is essential in endeavours with a long gestation time; thirdly, apart from responding to environmental changes, it is vital to influence them; and fourthly, explicit and visible goals serve as an inspiration to organizational effort.

If the selection of R & D projects is left completely to the R & D department, then the decisions are likely to be taken on a project by project basis. The sole criterion is likely to be the individual merit of a project, rather than its contribution to a balanced set or portfolio of projects advancing corporate goals. The problem is that projects are interdependent via resource constraints. Thus, in practice, funds are restricted, and projects compete with each other for equipment, manpower, materials, infrastructure, and project management. Maximization of the contribution of a whole portfolio is invariably more important than the maximization of the contribution of the separate projects. In fact, a portfolio can develop group characteristics, either by design or by chance. And, these characteristics may involve short- , medium- or long-term considerations, or a balanced emphasis on all these.

A linkage between corporate goals expressed through a corporate strategy and the choice of a portfolio of projects can be achieved via the R & D strategy (Figure 8.3).

The R & D strategy thus performs for the R & D unit a role similar to the the role that the corporate strategy plays for the organization as a whole (Table 8.1).

Table 1 : Roles of Corporate and R & D Strategies

Area of influence	Corporate strategy	R & D Strategy
Goal(s)	Related to business environment	Related to corporate environment
Resources	Allocation between functions (marketing, production, R & D, etc)	Allocation between projects
Business areas	Product/market strategy Product/market mix	Technology/product strategy Project portfolio
Time scale	Long/medium/short term balance	Long/medium/short term balance

4. Resource Allocation to R & D

Investment funds are invariably limited, and these limited funds have to distributed between short-term and long-term returns. R & D has to compete for these funds with production, advertising and other activities. In this competition, the real problem is that R & D expenditures are not easy to justify on a cost:benefit basis, for it is rarely possible to correlate R & D expenditures with profitability because quite apart from R & D

there are several other factors that contribute to prfitability such as pricing, marketing successes, tax changes, economic conditions, etc.

It seems that the amount of money to spend on R & D is one of the most difficult problems facing top management -- hence, it is usually decided through a judgement based on the value system of corprate leadership, and through negotiation between the director of R & D and the top management. What is clear is that a "zero" R & D budget is against the interests of the organization because even if R & D only serves the purpose of forecasting what are the likely technological changes in the areas of concern to management or enhances the capability to choose technologies for import, it justifies a non-zero expenditure.

In the absence of an accepted basis for the allocation of an budget to the R & D unit, there are a number of approaches to the problem. These include allocation on the basis of

(1) inter-firm comparisons,
(2) fixed percentage of turnover,
(3) fixed percentage of profits,
(4) reference to previous expenditure levels, and
(5) casting of an agreed programme.

It would be expected that competitors would spend roughly similar amounts to stay in business, and therefore, a rough guide to how much expenditure to be incurred on R & D is the competitor's expenditure, R & D manpower, recruitment policies, etc. But, there are several problems with this approach. Different companies compute their R & D expenditures differently. Their product-mixes may not be the same.

A constant percentage of turnover is the most frequently used method. Its shortcoming is that the present turnover is the result of past investments, but the R & D expenditure must be correlated with future turnover.

Linking the R & D expenditure to profits carries the unfortunate implication that R & D activity is a luxury that should be indulged in only when the company is making profits. In fact, present profits may well be the result of inadequate R & D expenditures in the past. Further, the building up R & D capability is associated with long lead times, and therefore once an R & D team is destroyed, it cannot be rebuilt easily and quickly. For all these reasons, few companies link R & D expenditures to profits, though in hard times the axe often falls first on the R & D budget.

The absence of acceptable criteria makes it even easier to use as a starting point the previous allocation plus a margin to cover inflation, expansion, new equipment, etc.

Finally, it is possible to agree on an R & D programme and then work out a R & D budget by costing the agreed programme.

Since no single method provides a satisfactory basis, judgement and negotiation will inevitably play an important part in the allocation of an R & D budget. Consideration should however be given to the following:

(1) expenditure by competitors,
(2) adequacy of previous allocations in relation to the needs of R & D strategy,
(3) long-term growth objectives,
(4) the need for stability and smooth change in order to avoid violent fluctuations in the R & D budget which would cause painful contractions or difficult expansions,
(5) distortions due to large projects.

5. Resource Allocation within the R & D Unit between Projects

(1) "Gap Analysis" : The corporate long-range plan will specify company objectives in terms of a quantitative parameter such as profit over a number of years. This profit is the resultant of the contributions of a number of products. But, most products have a limited life, and the profit contributions from products at the beginning of the planning period will diminish and even disappear in course of time. Hence, their will be a "gap" which will have to be filled by the introduction of new products (Figure 8.4). "Gap Analysis" shows the magnitude of the task facing R & D which is responsible for ensuring that the required new products are available when required and are a kind that will make adequate profits. In addition, "gap analysis" provides a more rational basis for estimating the funds required by R & D.

(2) Product Life-cycles : The pattern exhibited by the profit and volume histories of most products is shown in Figure 8.5. After an initial period of unprofitable trading when there is low volume and losses, the profit life-cycle rises and falls ahead of the volume life cycle because of high margins during the innovation phase and increasing competition during the mature phase. The product life-cycles indicate a number of consider-ations to be borne in mind in making allocations within R & D :

(a) the different behaviour of the profit and volume life-cycles,
(b) while the initial profit growth following break-even is attractive in the case of successful products , the risk of failure is also high,
(c) initial success relies heavily on the ability to develop innovative products, but continued profit- ability depends more on manufacturing and marketing to maintain sales volume with low production costs.

(3) Single-product Companies : Whereas "gap analysis" is necessary for understanding needs in a multi-product company, the pattern of product life-cycles shows the problems of a single-product company. Even a single product can go through a succession of changes sufficiently important for each to be regarded as a separate product in its own right -- e.g., various materials (cotton, rayon, nylon, polyester, and glass) used as tyre cords (Figure 8.6). The tyre-cord life-cycles show the typical form, but in addition they show that the life span of a a tyre-cord material is about 35 years and a new tyre textile is introduced every 10 to 15 years. Thus, it is important to

(a) anticipate the introduction of new technologies which may threaten established products,
(b) estimate the rate at which new products are likely to appear,
(c) estimate the rate at which new products will capture the market,

(d) decide when to enter the market with a competitive new product.

Timing is essential for these crucial strategic decisions.

The requirement for profit growth can now be combined with the contributions obtainable from each of a family of successive products (Figure 8.7). But the shapes of the individual profit curves are the result of R & D decisions. They are made to happen, and the shapes of the individual curves are determined by the allocation of resources to individual R & D projects.

The ways in which R & D decisions (and the allocation of resources to individual R & D projects) influence the shapes of the profit curves of individual products and therfore the shape of the corporate profit curve is shown in Figure 8.7. R & D investments can influence the following:

(1) short-term development of an existing product,
(2) extension of product life,
(3) early introduction of a new product,
(4) late entry with a new product,
(5) long-term development of a third-generation product.

Short-term development of an existing product may the response to the threat of the pressure of competitors on price and improvements. It may involve R & D effort devoted to product improvement and reduced manufacturing costs.

Extension of product life through R & D is a highly desirable policy because manufacturing facilities for the existing product are a "sunk" cost. But this extension must be undertaken as part of a deliberate policy which ensures that adequate provision is made for the new product which will eventually replace the existing product.

The early introduction of a new product -- an "offensive strategy" -- is a high risk strategy with opportunities for a high financial payoff.

Late entry with a new product to allow a competitor to pioneer the market is a low risk/low payoff "defensive strategy". Because it is less demanding to be a follower than an innovator, the R & D investment is likely to be lower both with respect to the cost of developing the new product and the involvement of high calibre technologists.

Long-term projects are to safeguard against a future when even the second-generation product becomes obsolete and will need to be replaced. Such projects involve several choices of R & D investment particularly when it is not clear what form the third-generation product will take. The choices range from initiation of a major R & D programme to "wait and see". The alternative actions include:

(a) technological forecasting and monitoring to identify and interpret significant developments,
(b) a minimum "foot in the door" investment in R & D capability to facilitate rapid response to future technological threats,
(c) a major R & D programme to wrest the iniative.

If funds were unlimited, all five of the above approaches can be adopted simultaneously. In practice, a choice has to be made, and it may be necessary to sacrifice short-term interests for long-term gains. Hence, priorities must be developed.

(4) Analysis of Resource Allocations : The reasoning applied to a single-product company is equally applicable to multi-product concerns, but it is necessary to analyse the spending opportunities under general headings such a short-, medium- and long-term work, existing and new products, and existing and new technologies. Other possible classifications are between produt and process development or between product areas. The total R & D budget can then be apportioned (Figure 8.8) between these classifications to generate a particular portfolio balance. The analysis of current allocations along these lines is also useful because it can reveal imbalances and indicate what changes are necessary.

6. Factors to be considered in Formulating an R & D Strategy

There are three main informational inputs to the R & D strategy :

(1) environmental forecasts (O and T),
(2) capability analysis (S and W), and
(3) the corporate strategy (Goals).

From Figure 8.3 by working from top to bottom, it appears that project selection must be derived from the R & D strategy. But, strategy formulation is an iterative process, and the potential projects must be considered in formulating the strategy -- after all, it is projects that make the strategy feasible. Further, the likely allocation of resources to R & D must be considered in choosing an R & D strategy.

Environmental forecasts : Just as environmental forecasting is necessary for corporate planning in order to establish what can be done to exploit the opportunities and meet the threats arising from possible future changes in the environment, the R & D strategy -- which is an extension and integral part of the planning process -- uses forecasts in a similar fashion.

R & D is concerned primarily with the changes in technology which will occur in the future. But, technology cannot be forecast in isolation of economic, social and even political factors. Hence, technological forecasting must cover much of the

same ground as general business forecasting.

Knowledge of how competitors will respond to environmental change would be extremely valuable. This knowledge is very difficult to obtain, but what is possible is a deduction of what logical reactions competitors might be expected to produce.

It is not easy to answer the question : which is the competition? The most dangerous competition may come from unexpected quarters, and forecasting can reveal new competitive technologies -- innovation by invasion -- and businesses arising from them.

Thus, the value of environmental forecasting in strategy formulation can be seen in three main areas :

(1) identification of future threats and opportunities,
(2) avoidance of technological surprises,
(3) identification of new competitive technologies and businesses.

Comparative technological cost effectiveness : Just like products, technologies too have life-cycles. The body of knowledge in a technology increases until it reaches a point where further research yields new knowledge whose incremental commercial benefit becomes negligible. When this stage is reached, investment in a new branch of knowledge is likely to offer far more promising opportunities for new products, processes, or product improvements. Such a reorientation is not easy to achieve. The relevance of advances in a new technology may be completely missed if the company has no experience in it. "Technological forecasting" can help in spotting the relevant trends, but does not help in suggesting what should be done about the new trends. The response rate of an R & D department may be very slow, because its major asset, people, have vested interests in a certain profile of skills, and the new trends invariably demand new profiles. The skill profile of a particular set of R & D personnel can be changed only within a narrow range. And the personnel cannot be replaced easily. Technologists are not nade redundant even when their expertise is become of decreasing value. In fact, even the decrease in value of expertise may neither be noticed or acknowledged. The obsolescence of R & D expertise is not as easy to detect as that of plant and machinery. Thus, long after the economic returns from a technology have diminished, an R & D department may still be coming up with new projects pertaining to that technology.

These difficulties tend to occur in a large mature organization which is no longer growing rapidly, and this constitutes an aggravation because change can be accomodated more easily in growing organizations. Even though the imbalance between dying and emerging technologies can be redressed by the induction of new specialists, the mature organization aiming to provide security for its employees finds it difficult to make the necessary responses.

The situation can be alleviated by re-training (education does not ceasewith graduation), re-employment (in different areas not necessarily of R & D) and recruitment.

Risk vs Payoff : Risk, which can be analysed quantitatively by weighing the expected payoffs against the probabilities of the occurrence of the outcomes, is inherent in R & D strategies. Risk is associated not only with respect to the individual projects, but also with the portfolio.

The risk associated with the portfolio of projects must be a major concern of the R & D strategy, and should reflect the corporate attitude. But this risk is spread over a mix of projects each of which is associated with its own level of risk. A multi-project laboratory can achieve a mix of offensive, high-risk and defensive low-risk projects, the mix reflecting the risk propensity of the corporate and R & D strategies.

"Risk analysis" might suggest that a large company, able to spread its risk over a larger number of projects, would opt for an offensive strategy, in contrast to a small company which would favour a defensive strategy. In practice, the opposite may also be true. Maturer organizations may be more risk averse, and there tends to be an attenuation of the willingness to accept risk as one goes down the heirarchy.

Planning can never remove the risk from business decisions. But, at least one can hope that a process of rational analysis will enable the avoidance of most of the obvious pitfalls and an assessment of the risks inherent in the identifiable uncertainties. But, however careful the analysis, there is always something which is either overlooked or could not have been anticipated. The planning process ought to lead to a quantification of known risks but it would be mistaken to assume that this can reflect every possible eventuality.

Capability Analysis : Before a strategy is formulated, it is vital to make an objective and realistic assessment of strengths and weaknesses from the standpoint of present and future requirements. The strengths and weaknesses of the corporation have a bearing on the R & D strategy -- for example, a company strong in marketing and production is unlikely to succeed with product innovation, and a company with strong R & D will be better suited to coming up with innovative products. But, there are also the strengths of the R & D unit which should appraised. Such an appraisal may take the form shown in Figure 8.9 which represents not only the current strength but also the technological capital, i.e., the technological capabilities required to meet future challenges. The gap between the current strengths and the future requirements of technological capital highlights how relevant the present capabilities are for the

future and also what build-up of capability is necessary. Obviously, strategy formulation and R & D strengths must be part of a combined exercise.

7. Selecting the R & D Strategy

The formulation and selection of an R & D strategy is a process of iteration rather than a one-shot decision-making process. Such a iterative process leading to the evolution of a strategy is natural considering the inter-relationship between corporate strategy, environmental analyses, capability audits, the protfolio and individual projects. Also, the choice between different types of strategies, e.g., between offensive and defensive strategies, may be more a question of emphasis than of exclusive selection.

Offensive Strategy : High-risk, high potential payoff strategies demand strengths in technological innovation, the ability to see new market opportunities in technological terms and the competence to translate these insigths into commercial products. Studies on the effect of company size on innovation show that many of the major innovations of the past few decades have come from small companies. However, some market leaders may not be able to avoid an offensive strategy to prevent their position being destroyed by a new product from a competitor. Between the extremes of a small company and the market leader, there is a broad range where there are special reasons arguing for an offensive strategy.

Defensive Strategy : A low-risk low-payoff defensive strategy is suitable for a company with strengths in production and marketing (rather than R & D) able to earn profits under conditions of stiff competition through low manufacturing costs. However, from the point of view of long-term survival, it must build up sufficient technological "muscle" (particularly at development as distinct from research) to make a quick response to a competitor's innovation.

Absorbtive Strategy : Licensing offers many opportunities through the purchase the results of another company's R & D investments. In other words, a company need not rely only upon innovations generated from in-house R & D. However, internal technological strength is required to identify what to license and to absorb what has been obtained through licensing.

Interstitial Strategy : An interstitial strategy is based on avoiding direct confrontation particularly with the market leaders. Instead, the aim of a company following this strategy is to find a niche in the market suitable to its strengths and corresponding to the weaknesses of its competitors.

Market Creation : Sometimes, but not frequently, a chance arises of creating a completely new market rather than substituting for an existing market.

Maverick Strategy : There are situations in which the characteristics of a new technology several reduce the market for the product to which that technology is applied. Since the market leader stands to lose a great deal, it is unlikely to introduce the new technology. But, an outsider -- a maverick -- has nothing at stake and introduction of the new technology represents growth for the maverick even the total market for that product may be reduced. In the case os stainless steel razor blades, Wilkinson Sword Ltd was the maverick wich gained at the expense of Gillette, the market leader.

Acquisition of People : Instead of buying a competitor's technology, a company may acquire his key staff or even a whole project team. Sometimes, such an acquisition may also suit the competitor because a change in his policies may make some of his human technological capital redundant. Thus, many of the competitor's personnel problems may be solved by their being acquired by another company.

Acquision of Companies : Technology may be one of the reasons why a large company may wish to buy a smaller firm which may be highly innovative but may be unable to sustain R & D costs or to carry out the production and marketing. In such a situation, the large firm may use its financial strength to purchase the technological assets of the smaller firm.