R&D PROJECT ASSESSMENT AS AN INFORMATION AND COMMUNICATION PROCESS*

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The paper has three main objectives, viz, *to emphasize the need for informed project assessment as central to the effective management of R&D by Australian businesses; to argue that different assessment techniques will be applicable to different stages of a project's development; to emphasize the importance of R&D project assessment as an information and communication process which helps to promote a firm's goals. In addressing these issues the paper highlights some of the ways in which managers of Australian companies can learn from overseas experience and outlines some of the challenges facing Australian management at this time.*

Keywords: research and development, project assessment, information, organization, communication

INTRODUCTION

There is growing concern that Australian industry, particularly manufacturing, is becoming increasingly uncompetitive in world markets. While Australia continues to rely heavily on its traditional sources of export earnings from the rural and mining sectors it is world trade in manufactured goods which has grown most rapidly in recent years. An increase in the pace of technological innovation is necessary if Australian manufacturing industry is to be revitalised so as to improve its export performance, create employment, and make a greater contribution to the nation's economic development.

Any move toward enhancing Australia's international competitiveness will depend in large measure on the quality and quantity of R&D activity and on the application of the results to industrial and economic growth. R&D activity is a crucial determinant of the pace of process and product innovation necessary to promote industrial competitiveness and exploit market opportunities, whether domestic or international. Even where there is considerable reliance on imported technology, as is the case in Australia, maintenance of a strong R&D performance underlies the nation's ability to embody imported technology, both in processes that

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suit its industrial needs, and in products which can compete effectively on international markets. Unfortunately, Australia's performance in R&D activity, especially industrial R&D (IR&D) is poor by international standards.[1]

There seems to be, in general, a poor level of technological awareness among Australian business management, resulting in a failure to perceive the importance of technology in determining business growth and competitiveness. Australian managers typically do not perceive R&D to be a part of strategic considerations.[2] R&D spending is regarded as discretionary, defensive in orientation, rather than a necessary feature of business activity. Even where opportunities for technological advancement are clearly perceived managers of Australian companies seem generally risk averse, and prone to adopt a follower's role in respect of technological advances successfully implemented overseas.[3]

Certain recommendations have been proposed recently as to how the quality of decision-making by the managers of Australian industry can be improved. The OECD report on Australia's science and technology policy emphasizes the importance of promoting a wider understanding of the various steps that are necessary to transform a scientific discovery into a product or service for customers while recent reviews of industry and technology policy lament the absence of a 'productive culture' in Australian industry.[4] One recent initiative, the National Industry Extension Service aims to support management awareness programs for industry leaders and managers, to emphasize the importance of R&D in promoting the benefits of technological innovation, and to assist managers in the design of R&D programs, the acquisition of resources for R&D, and techniques of effective management of R&D.[5]

Since a condition of effective management of R&D is that decision-makers understand how to employ extant techniques of project selection and evaluation, attention will need to be paid to this area. Indeed, it might be argued that one reason for the low priority accorded to IR&D in Australia involves management's inability to properly assess the merits of competing projects. Where a basis for informed decision-making as regards project selection and evaluation is lacking, it is likely that fewer of a firm's scarce resources will be devoted to R&D activity.

This paper has three main objectives. First, to emphasize the need for informed project assessment as central to the effective management of R&D. Secondly, to argue that different assessment techniques will be applicable to different stages of a project's development. Thirdly, to emphasize the importance of R&D project assessment as an information and communication process which helps to promote a firm's goals. In addressing these issues I hope to highlight some of the ways in which managers of Australian companies can learn from overseas experience and outline some of the challenges facing Australian management at this time.

IMPORTANCE OF R&D PROJECT ASSESSMENT TECHNIQUES

The selection of R&D projects for funding is a special case of the general problem of the optimal allocation of scarce resources (e.g., money, manpower, facilities) among alternative uses. Decisions must be made as to which new proposals, if any, should be selected for funding, which existing projects should be continued and which should be terminated, and the amount of resources which should be allocated to each project. Economic efficiency requires that the firm determine which allocation of resources to alternative R&D projects will make the greatest contribution to the firm's goals. The process of project assessment is embedded within a firm's budgeting and planning process and typically involves a series of evaluations and decisions made by various people with different ends-in-view, at different levels of the corporate organizational heirarchy.[6]

The R&D project assessment process may be undertaken on an informal basis where subjective judgements and intuitions are used to rank candidate proposals, by employing formal techniques of assesment, or by any combination of assessment procedures.

Standard R&D project assessment techniques may be grouped under three headings, *viz*, Classical methods, Portfolio methods and Decision-Theoretic methods. Classical assessment techniques include checklist models, profile charts, scoring models and economic indices such as the rate of return and net present value. Portfolio models, employed to determine a portfolio of projects rather than the rank ordering of individual projects, are based on mathematical programming, i.e., linear, non-linear, integer and dynamic programming, which treat the R&D project selection decision as a constrained optimization problem. Decision-theoretical models, which include risk analysis and utility theory are based on developments in the theory of rational decision-making under risk and uncertainty. They focus on the consequences of selecting and rejecting various projects and the expected benefits and costs thereby incurred.[7]

To date, the more sophisticated models have not found wide acceptance among companies undertaking R&D projects. A recent survey of the extent to which they are used in the UK concluded that

> there is a significant gap between the prescriptions of academics and consultants and the actual usage of advanced techniques for project planning and control. Project selection techniques tend to be relatively simple, e.g., checklists and project profiles . . . although there is some evidence of the successul use of risk analysis, risk/return profiles and to a lesser extent mathematical programming.[8]

Historically, reasons for the low level of acceptance of certain of the more rigorous techniques of assessment include management's inability to use elaborate mathematical and decision-theoretic models, the failure of various techniques to capture the reality of the R&D assessment process, the difficulties of meeting the data requirements of these models in an environment characterized by both commercial as well as technical uncertainties, and the lack of organizational stability needed for their introduction and continued use.[9] While data are lacking as to the extent to which such techniques are employed by Australian business there is little reason to believe that the situation is any different in this country.

Despite their limited use to date, there are a number of advantages of employing formal techniques of R&D project assessment. Use of formal assessment techniques may be expected to promote consistent decision-making in the R&D area. They allow management to more clearly identify those projects or ideas which should be abandoned and those which deserve to proceed. They enable decision-makers to better appreciate the sort of data which is needed to make informed judgements on project evaluation. They have the capacity to expose implicit assumptions underlying different proposals and to highlight areas where technical and commercial judgements are necessary. They have the added advantage of involving different departments of the firm, e.g., production, marketing, finance in the R&D project assessment process so as to foster co-operative working relationships between those groups. In short, formal project assessment methods promise to foster a more effective allocation of the firm's resources both within a given R&D budget and between R&D and other areas of the firm's activities.[10]

RATIONALE FOR A STAGED-METHODOLOGY OF R&D PROJECT ASSESSMENT

The question arises as to the most appropriate model or type of model to use in R&D project assessment. When couched in this manner however the question is misleading. No single model or type of model fits every assessment task and no single model dominates other models over all stages of the R&D process in respect of its usefulness as a decision aid.[11]

The specific model or type of model to assess a project must be commensurate with the quantity and quality of data available at the time the assessment is made. Since the quantity and quality of data will vary between different stages of the R&D process we can expect that different assesment techniques will be applicable to different stages of the project's development.

While a number of stage classification schemes for R&D activity have been discussed in the literature, each stage defined by its objectives and scope of activities,[12] for our purposes it is useful to classify these stages according to the OECD classification of R&D activity as adopted by the Australian Bureau of Statistics.[13] On this classsification scheme three categories of R&D activity are distinguished, *viz,* Basic Research, Applied Research and Experimental Development.

A fourth stage, commercial investment may be expected to follow upon successful completion of the other three stages. This represents culmination of the R&D effort. It should be emphasized however that there are no sharp boundaries between these categories and, depending on the purpose for which it is undertaken, the same activity might be defined in different ways. Also, these activities need not occur in strict chronological order. Frequently R&D activity falling into one or other category cannot be undertaken except in concert with R&D activity in another category.

In the initial phases of an R&D project costs are typically very low and risks are very high.[14] As the project progresses from the basic research stage to the experimental development and commercial investment stages there will usually be an exponential rise in cost, accompanied by a rapid decrease in the level of risks. The cost/risk relationship manifested by R&D activity in a typical manufacturing firm can be depicted as in Figure 1.[15]

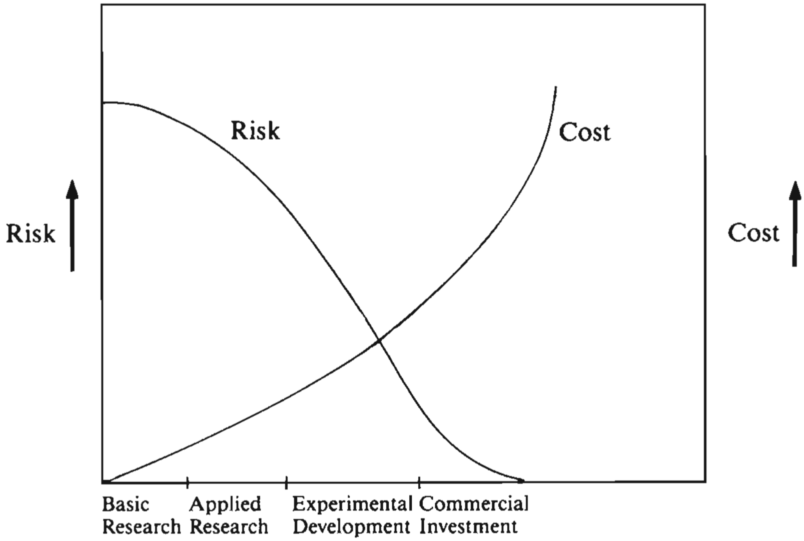

FIGURE 1

While R&D project assessment is a continuing process, the nature of the assessment is different for a research as opposed to a development project. In Mansfield's words

> As a project moves from the laboratory toward the market it receives more intensive scrutiny from both a technical and an economic angle. In the early research phase the screening of proposals will probably be quick and informal since costs at this stage are low and predicting outcomes is very

difficult. But as projects enter the development phase where costs and predictability are higher, they require a far more detailed process of economic evaluation.[16]

Since, in the initial stages of an R&D project there are high levels of uncertainty attached to estimates of key assessment criteria, those models which have demanding informational requirements are inappropriate. The assessment techniques best suited to a project in its early stages are those requiring a mininum of quantitative data, e.g., checklists, profile charts, estimates of rate of return, etc. As the project advances into the applied research and experimental development stages, there is a progressive increase in the quantity and quality of information concerning production criteria (e.g., likelihood of technical success, future applications of new technology generated, compatibility with existing manufacturing operations), marketing criteria (e.g., product advantage, licensing potential, probability of commercial success), and financial criteria (e.g., manufacturing and marketing investment). Given that a major objective of the R&D effort is to acquire this sort of information, thereby reducing uncertainty, it can be expected that in the advanced stages of an R&D project those techniques can be employed which place more demands on the accuracy of the input data used in the assessment, e.g. portfolio techniques, decision-theoretic models and classical techniques such as estimates of net present value.

In the initial phases of an R&D project, when risk and uncertainty is at its highest, there is little point in employing those sophisticated assessment techniques which demand quantitative data. As the R&D project proceeds, and as levels of uncertainty are reduced, there is increasing scope for the use of more sophisticated techniques. Furthermore, since each successive stage of the R&D process involves an ever-increasing financial commitment, the necessity for sound economic evaluation increases. For this purpose it is important that as many of the relevant costs and benefits of the project be quantified as is possible.

The region where the cost and risk curves cross is significant and may be regarded as the 'critical decision point' in the R&D process. While costs of a typical R&D project are very low in its early stages, there comes a time when substantial funds must be committed to the project if it is to continue. If, at this time, the risks and uncertainties attached to certain key assessment criteria are still high, it might be appropriate to terminate the project. If, on the other hand, those risks and uncertainties have been reduced to a comfortable level by the time at which substantial funds must be allocated, there are good reasons for continuing the project.

The above considerations point to the use of different assessment techniques at different stages of the R&D process. Ideally, the information resulting from the R&D effort at a given stage should fit the informational requirements for pre-evaluation of the succeeding stage. Moreover, the assessment techniques for stage pre-evaluation must be selected on the basis of the 'tool must fit the need' point of view.[17] While the cost/risk relationship exemplified by a particular R&D project will determine the appropriateness of particular techniques to particular stages, classical models such as checklists, profile charts, scoring models and simple economic indices generally will be most appropriate in a project's early stages, while portfolio and decision-theoretic models and sophisticated economic evaluation become more appropriate in the advanced stages. The technique or techniques to be employed as decision aids at the 'critical decision point' will depend on the extent to which levels of uncertainty regarding key determinants of a project's success have been reduced.

Thus far a crucial question has not been asked: who is to undertake the assessment? This leads us to consider the *process* of R&D project assessment. In recent years it has become increasingly recognized that as much attention needs to be paid to the implications of project assessment as an information and communication process to promote organizational goals, as to the merits of alternative project assessment techniques.

PROJECT ASSESSMENT AS AN INFORMATION AND COMMUNICATION PROCESS

An increasing amount of criticism is being levelled against the assumptions underlying the formulation and use of R&D project assessment techniques.[18] In general, the R&D project assessment decision has been modelled as a 'decision event' (i.e., accept or reject). The models seem to be constructed for a single decision-maker who has clearly defined goals, comprehensive information about the characteristics of alternative proposals, and can articulate in detail the consequences of accepting different proposals. Typically, it is assumed that candidate projects can be assessed independently of each other on economic grounds and a decision made as to which projects best meet a given set of assessment criteria.

The reality of the situation is that R&D project assessment typically is carried out by multiple decision-makers, at different levels of a firm's organizational hierarchy, emphasizing different assessment criteria in a dynamic organizational environment. The information necessary for assessment, e.g., project risks, costs, returns, manpower availability, resource trade-offs, etc., are highly fragmented and scattered throughout different departments of the organization. Organizational goals and constraints are often ill-defined and evolving and can be non-economic as well as economic in nature. Budgets for R&D are not so much 'given' as determined by an iterative, recycling process involving different departments and divisions within the firm. There will seldom, if ever, be a particular R&D resource allocation decision which is regarded as 'optimal' from the perspective of all departments in the firm.

Recognition that decision-making in real world corporate environments is influenced by a great number of organizational and behavioural factors leads to a change of perspective as to the manner in which extant techniques should be employed to aid R&D project assessment. The models reflect only the analytical aspects of assessment with minimal behavioural content. They give the false impression that agreement exists just because different departments have supplied input data pertinent to assessment. If, as is likely, there are interpersonal and inter-group rivalries and diverse viewpoints concerning goals, constraints and relevant assessment criteria, accompanied by the lack of a 'common language' between technical, marketing and financial personnel, use of R&D project assessment techniques can be a source of conflict in many organizations. Real or genuine participation in R&D project assessment by different departments amounts to much more than the provision of quantitative input into some R&D project selection model. Indeed, the important interpersonal exchange process necessary to achieve organizational consensus may be inhibited if premature quantification is imposed by a project assessment technique. What is needed is an appreciation by all participants of the relevant value systems of others involved in the assessment process.

At least three important behavioural needs must be satisfied before any R&D project assessment technique can be used effectively.[19]

(i) There must be agreement at all levels of the organization as to organizational goals and constraints. Since it is the goals of the firm which provide the rationale for the R&D effort, such effort must be assessed in terms of the extent to which it is expected to promote these goals. The greater is the understanding of the firm's goals by personnel at different levels of the organizational hierarchy, the greater is the likelihood of consensus as to assessment criteria. For their part, management should not set organizational goals without a full understanding of the organization's technical, marketing and financial capacity to achieve them.

(ii) The various personnel engaged in R&D project assessment must fully understand the nature of the projects under consideration. This implies a good degree of knowledge of the details of each proposal and its effect on the firm's operations as well as an awareness of the feelings and attitudes of others toward candidate projects.

(iii) There needs to be explicit awareness by all personnel that attempts to achieve organizational goals through R&D effort requires co-operative effort. Those involved in R&D project assessment whether as sponsors of proposals, suppliers of information or key decision-makers, need to appreciate the larger needs of the organization relative to their own needs or those of their particular department. This means that they must be willing to engage in a co-operative endeavour involving the sharing of information and open discussion of alternative strategies to achieve the goals of the larger organization of which they are a part. In his arguments to the effect that, the closer the link between marketing and R&D, the greater the likelihood of commercially successful innovation, Mansfield reminds us that "the interface between R&D and the other functions has a very serious effect on the productivity of industrial R&D".[20] This is just one example where organizational integration and commitment in the early stages of project assessment can facilitate co-operation during the development and commercialization of the project.

As a result of such considerations we concur with those commentators on R&D project assessment techniques who argue that, if these organizational behavioural needs are to be satisfied, some type of 'semi-structured open forum' must accompany the use of the relevant techniques. In the quest to construct a suitable forum, model builders have proposed the use of so-called 'Organizational Decision Methods'. Two methods which have been suggested are Behavioural Decision Aids and Decentralized Hierarchical Modelling.[21] We will now provide a very brief outline of the essential thrust of each new approach.

Behavioural Decision Aids

The least formal type of behavioural decision aid involves what is known as the Q-Sort/Nominal-Interacting (QS/NI) Process which combines the use of psychometric methods and controlled group interactions.[22] The QS/NI process can be broken down into at least three stages.

In the first stage, individuals from different departments of the firm complete a Q-sorting exercise. Each is given a deck of cards with each card identifying a candidate R&D project. Participants then sort and re-sort the cards into five priority categories (from very high priority through to very low priority) according to a pre-defined set of assessment criteria. The results are then tabulated in a tally chart and displayed to all participants. The process thus far enables individuals to document their own attitudes and reveal their preferences. In the second stage participants can interact and discuss the results. Each individual, however, has full control over the extent to which he or she participates in the sharing of opinions, exchanging of data, challenging others, responding to questions, etc. Individuals can respond or remain silent as they wish, thereby preserving the anonymity of the tally charts and the holders of minority opinion. At this stage the participants are confronted with a diversity of opinions to be reconciled. In the third stage the sequence of individual Q-sort period (the so-called 'nominal period') and a group discussion period (the 'interacting period') can be repeated for several rounds. Subsequent nominal periods enable participants to restructure their thoughts privately, while subsequent interacting periods provide them with the opportunity to sharpen perspectives and work towards consensus.

As indicated, an essential starting point for R&D project assessment is a consensus set of prioritized goals. The QS/NI process has been found to be useful in promoting this consensus. Once a consensus set of goals is established extant techniques of project assessment can be used in conjunction with the nominal interacting process. The particular assessment techniques employed will depend on the type of project. For Basic Research, where the data are often highly uncertain and subjective, checklists and profile charts could be used as analytical aids in combination with the nominal-interacting process to facilitate the exchange and classification of opinion. For applied research projects, where data for evaluation are more certain and more comprehensive in scope, it would seem appropriate to perform a Q-sort exercise as a project screening device, in conjunction with assessment techniques such as economic indices and risk analysis models as decision aids in the nominal interacting process. For experimental development projects the amount and quality of data may enable sophisticated computerized portfolio and decision theory models to be employed. The input data to be used for assessment purposes could be generated in a nominal setting while the results from application of various techniques could be evaluated in an interacting setting. Whatever the type of project, the assessment technique satisfies the need for an analytical aid while the nominal-interacting process helps to satisfy the organizational behavioural needs.

Empirical studies reveal that the Q-sort method provides the analytical structure for ranking goals for R&D while the nominal interacting process facilitates the generation of ideas and suggestions for defining the goals. The combined QS/NI process can elicit information required, promote interpersonal understanding and interdepartmental collaboration, sharpen perspectives on R&D strategy, foster consensus on project rankings, and general feelings of group identity, teamwork, and commitment to goals, which are crucial for effective organizational decision-making.[23]

Decentralized Hierarchical Modelling

Decentralized Hierarchical Modelling, with its origins in mathematical programming theory, has been shown by Kocaoglu to be a viable approach to pre- and post-program evaluation, resource allocation and a variety of management situations.[24] The approach is based on the recognition that the collective judgements of informed personnel represents the best information available to evaluate complex programs when there is uncertainty regarding the impacts of alternative decisions. The approach is now receiving attention in the literature on R&D project assessment.[25]

As an aid to R&D project assessment the approach involves various personnel in different departments of a firm and at different levels in its organizational hierarchy, responding and counter-responding by computer, iterating until a consensus portfolio is achieved. In one of its forms, the process begins with top management stipulating firm goals and sending budgetary guidelines to divisional managers who determine priorities and send the information to the R&D manager. The R&D manager, advised by project management staff using standard assessment techniques, develops a portfolio of acceptable projects. The results are then sent back up the hierarchy. Comments and analysis are encouraged at every level. Calculations are done on computers with the information stored and readily retrieved by any participant. Upon receiving this information top management sends modified guidelines back down the hierarchy for another iteration. The procedure may be repeated several times until a consensus is reached.

There would seem to be a number of advantages of employing decentralized heirarchical modelling in R&D project assessment. One advantage is that the procedure is a familiar one, following the flow of most organizational budgeting exercises. A second advantage is that it is efficient. The number of face-to-face meetings is minimized. Participants in their own offices can call up data at any stage of the process, analyze the data, make criticisms or provide perspectives and alternative points of view and so on. A third advantage is that the process of sharing opinions, challenging data, asking and responding to questions, can be done in a way which avoids the well known social pressures which often characterize face-to-face meetings. As Souder and Mandakovic have concluded:

> The (decentralized hierarchical modelling) process thus appears to foster a more open and complete exchange of information resulting in the selection of more effective projects and the enthusiastic commitment of the entire organization to them . . . With the advent of microcomputers, the movement towards business integrated R&D departments, and today's renewed emphasis on formal decision analyses, we are poised for a new kind of growth in project selection modelling.[26]

More research needs to be undertaken on the implications of restructuring organizations to promote more effective R&D.[27] While organizational theorists tend to emphasize the potential benefits of alternative modes of organizing R&D the possible costs have received less attention. In particular, very little is known about the costs of implementing organizational decision methods of R&D project assessment.[28] Even so, one should not underestimate the relevance of recent work on Organizational Decision Methods for the entire area of R&D project assessment. Prior to recent initiatives, management theorists tended to view assessment techniques as enabling management to find cut and dried answers to questions about R&D. On the standard view the 'correct' R&D decisions resulted from collecting information about alternative proposals and using assessment techniques as an algorithm of choice. The new approach is based on a recognition that the data for R&D project assessment are not only very subjective and diffused throughout many departments of an organization, making their collation extremely difficult, but much of it may not even become meaningful until fully communicated to staff in different departments and views exchanged as to its interpretation. On the new perspective, project assessment techniques become aids to inter-department communication and interpersonal interaction. Their proper role ". . . . is to serve as a *laboratory* for testing policies, sharing opinions, asking hypothetical questions and stimulating inter-departmental interactions throughout the *entire organization.* To do this they must be used as part of some larger process such as (Organizational Decision Theory)".[29]

SOME IMPLICATIONS FOR IR&D IN AUSTRALIA

If Australian businesses were to use organizational decision methods such as behavioural decision aids and hierarchical decision modelling, this could go some way to remedy the current situation where management generally fails to appreciate the importance of R&D in promoting industrial competitiveness.

The use of organizational decision methods promises to help solve what has become a perennial problem in product development, *viz,* the difficulty of transition of a project from R&D to production and finally to marketing. For some time now there has been concern as to how marketing personnel could be involved in R&D project assessment while maintaining the enthusiasm and motivation of scientific and technical people.

Historically, the lack of integration between R&D and marketing departments has constituted a significant barrier to product innovation in firms both overseas and in Australia. The greater the extent to which personnel in different departments of a firm identify with projects which promote corporate objectives, the greater the likelihood of achieving these objectives. In Australia, where business plans are less formalized than is the case overseas, the goals of firms may be expected to be much less clear to staff below top management. Employment of organizational decision methods in R&D project assessment can lead to a greater understanding by staff of firm goals and relevant assessment criteria. It can also enhance the success rate of product innovation by fostering co-operation between personnel in different departments from the earliest stage of a project. In view of the crucial importance of product innovation to Australian industry at the present time the employment of organizational decision methods deserves serious consideration by all firms engaged in R&D.

Compared to other OECD countries, Australian business leaders appear to have no systematic or planned approach to monitoring key technology development. Studies reveal that very few companies have any formal responsibility for a nominated director or technology manager to keep the Board informed about key process or product technologies.[30] At the same time some critics suggest that the main problem with IR&D in Australia is not the scientific or technical quality of the effort by the inability of business executives to understand and manage it. This has led to calls for the education system to produce more science-literate businessmen and business-literate scientists.[31] The use of organizational decision methods in R&D project assessment can help to address these problems as well. Not only will it facilitate greater awareness among key decision-makers as regards technological developments important to a firm's operations, but might be expected to promote the effective awareness of and response to changes in the market or competitor environment. The 'dialogue' between scientific and business personnel in different departments and different organizational levels within a firm which organizational decision methods facilitate, can foster the sort of communication identified as crucially important to the future competitiveness of Australian industry.

The use of organizational decision methods in R&D project assessment should also promote more understanding by staff in all departments of the typical firm about extant assessment techniques. This should serve to promote better management of R&D and commercially successful innovation. The less 'mystery' there is regarding the expected costs and benefits of R&D the more informed is decision-making about which projects should be initiated, which maintained, and which terminated. The more understanding there is generally about expected costs and benefits the less scope there is for psychological commitment or aversion to some project to override economic rationality. The more effective is investment in R&D seen to be, the greater should be the funds allocated to R&D by business over time.

CONCLUSION

While much has been, and is being, written as to how Australian industry can be revitalized so as to become more competitive in the world economy, commentators have for the most part focused on the initiatives that government can undertake to promote technological advance. However, government initiatives, by themselves, will not achieve aims such as increased R&D by the private sector unless the quality of decision making by business managers can be improved. This paper has sought to emphasize the need for more informed project assessment and its centrality to the effective management of IR&D. After presenting arguments to the effect that different assessment techniques are applicable to different stages of the R&D process, the paper went on to emphasize the importance of R&D project assessment as an information and communication process which promotes a firm's goals.

The use of organizational decision methods in R&D project assessment by firms in Australia promises to make for a more effective IR&D effort in the nation as a whole.

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13. See Australian Bureau of Statistics, *Research and Experimental Development All-Sector Summary, Australia 1984-85,* Canberra, AGPS, 1987. Basic Research is experimental or theoretical work undertaken to acquire new knowledge, regardless

of practical applications. Pure basic research is devoted to the advancement of knowledge *per se.* Strategic basic research is that directed into specified fields in the expectation of acquiring knowledge to solve recognized practical problems. For the most part basic research carried out by Australian industry is of a strategic, 'mission oriented' sort. Here the emphasis is on experimental or theoretical work directed into specified broad areas in the expectation of useful discoveries. Activities comprising this stage include long run research and the exploratory development of basic technologies. Applied Research is that undertaken to acquire new knowledge with a specific application in view, e.g., to determine possible uses for the findings of basic research or to determine new methods of achieving practical objectives. This stage includes research of a tactical or problem-oriented sort such as the identification of existing or potential processes and products, and their suitability for adaptation by the firm, patent surveys, studies of actual and potential resource constraints and bench scale research to determine technical parameters. Experimental Development is systematic work toward the creation of new or improved materials, devices, products, processes, systems or services. This stage typically involves the construction and operation of a prototype or pilot plant.

14. We may usefully distinguish between four different types of risk: i) real risk, as will be determined by future circumstances; ii) statistical risk, as determined by currently available data typically as measured actuarially for insurance premium purposes; iii) predicted risk, as predicted analytically from systems models structured from historical studies; and iv) perceived risk, as seen intuitively. For elaboration see C. Starr, R. Rudman and C. Whipple, 'Philosophical basis for risk analysis', *Annual Review of Energy,* 1, 1976, pp. 629-62. For the sorts of decisions made with respect to R&D project selection we can think of their 'riskiness' as based on perceived risk. As one of the referees has pointed out, the prevailing 'organizational culture' will affect the perception of risk/uncertainty attached to an R&D project. Following Kasper we can define organizational culture as "the fundamental value-and-belief perceptions, of thought patterns which filter perceptions, control the interpretations behaviour and actions of the organization members and which, in retrospect, serve as the horizon for justifications' (H. Kasper, 'Organisational-cultural aspects of the promotion of a favourable climate for innovation', in H. Hubner (ed.), *The Art and Science of Innovation Management,* Elsevier Science Publishers, Amsterdam, 1986, p. 48). We can readily appreciate how organizational culture influences the perceived riskiness of alternative R&D projects.
15. The stages of basic research, applied research, experimental development and commercial investment can be thought of either as stages in the life cycle of a typical product or, alternatively, as different project types..
16. E. Mansfield, 'How economists see R&D ', *Harvard Business Review,* 59, 6, November-December 1981, p. 102. As one of the referees emphasizes, the cost of reversibility of the project must be considered. If the project is irreversible or reversible only at substantial cost then initial investment is likely to be lower. On the other hand, a larger initial investment may be justified if it is expected to yield significant information on the particular project or on other projects. These sorts of considerations point up the complexities of R&D decision-making and suggest that over-simplified pictures, such as Figure 1, must be treated with caution.
17. cf. Albala, *op. cit.*.
18. A leading critic in this area is William E. Souder. The contents of this section are heavily indebted to Souder's views contained in Souder, 1978, *op. cit.*; Souder and Mandakovic 1986, *op. cit.*; W. Souder, 'Achieving organizational consensus with respect to R&D project selection criteria', *Management Science,* 21, 6, February 1975, pp. 669-681; W. Souder, 'Effectiveness of nominal and interacting group decision processes for integrating R&D and marketing', *Management Science,* 23, 6, February 1975, pp. 595-605.
19. See Souder and Mandakovic, *op. cit.*.
20. Mansfield, *op. cit.,* p. 101.
21. For a useful overview of both methods see Souder and Mandakovic, *op. cit*

22. For a more detailed discussion see Souder, 1977, *op. cit.*; Souder, 1978, *op. cit.*
23. Field studies suggest that this sort of behavioural decision aid can fill the need for a structured problem analysis and team building forum for organizational project selection and evaluation. See, e.g., W. Souder, 'Field studies with a Q-sort/nominal-group process for selecting R&D projects', *Research Policy*, 4, 1975, pp. 172-88. Further results indicate that consensus and collaboration problems between R&D and marketing may be alleviated by replacing interacting decision-making processes, which are typically used by many organizations, with a combined nominal-interacting process. For details see Souder, 1977, *op. cit.*
24. D. Kocaoglu, 'A participative approach to program evaluation', *IEEE Transactions on Engineering Management*, EM-30, 3, August 1983, pp. 112-118.
25. e.g., Souder and Mandakovic, *op. cit.*
26. Souder and Mandakovic, *op. cit.*, p. 41.
27. There is ongoing research into the structural characteristics of innovative and creative organizations and the characteristics of an innovative and creative organizational climate. A recent paper by Link and Zmud compares innovative efficiency as proxied by a measure of R&D efficiency between firms with organic and mechanistic R&D organizational structures where 'structure' refers to information flows and decision-making channels (A.N. Link and R.W. Zmud, 'Organization structure and R&D efficiency', *R&D Management* 16, 4, 1986, pp. 317-23.) The authors' results support the hypothesis that organic structures (those more open to individual initiative and discretion) experience greater efficiency in basic research, process related R&D, and long-term R&D activities, than do mechanistic structures. The authors suggest that further research should begin to explore the effectiveness of alternative managerial strategies for creating appropriate organizational structures for R&D groups.
28. A referee reminds us that Kenneth Arrow has highlighted the tradeoff between economies of scale and gains from specialisation in monitoring the external environment and internal communication costs. See, e.g., K. Arrow, *The Limits of Organization*, W.W.Norton and Co., New York, 1974. The design of complex organizations with their multiple tasks and divergent information needs requires a greater understanding of the influence of different organizational strategies on information flows and the effectiveness of such exchanges. While some useful results have been obtained, for example, R. Katz and M. Tushman, 'Communication patterns, project performance and task characterists: An empirical evaluation and integration in an R&D setting', *Organizational Behaviour and Human Performance*, 23, 1979, pp. 139-162, more research needs to be undertaken to determine the influence of formal organizational structures on communication patterns and its relevance for the use of organizational decision methods in R&D project assessment.
29. Souder and Mandakovic, *op. cit*,, p. 41.
30. See, for example, the results of the P.A. Technology Survey, *Attitudes to New Technology — An International Survey*', conducted by Market Opinion Research International for P.A. Technology Australia, Spring 1984. More than 200 senior executives in Australia, USA, West Germany, Britain and Japan in five industrial sectors, *viz*, engineering equipment/machines, medical equipment/disposables, domestic electrical appliances, industrial materials/chemicals and food/beverages, were questioned on their attitudes to technology. The survey shows that Australian business managers typically underestimate the strategic importance of technological investment and resources by comparison with their counterparts overseas. In particular, 60 per cent of the executives sampled in Australia reported that their firms monitor technology primarily by literature scans, while 26 per cent did so by staff attendance at seminars.
31. A. Clarke, 'Issues in applying university-based research', *Science, Technology and the Economy*, University of NSW Occasional Papers, No. 11, Sydney: University of NSW, 1986.