THE UNIVERSITY OF STIRLING

DEPARTMENT OF MANAGEMENT SCIENCE & TECHNOLOGY STUDIES

# CORPORATE STRATEGY FORMULATION IN THE CHEMICAL INDUSTRY:

## with special reference to bromine

by

Dov Tzidony

A thesis presented to the Board of Studies for Technological Economics for the Degree of Doctor of Philosophy

Stirling, Scotland, April 1983

## ABSTRACT

This study is an inter-disciplinary investigation into the nature of corporate strategy and the forces shaping industrial development with particular reference to a science based industry such as the chemical industry. The central objective of the study is to analyse the critical role of technological change as a major force in strategic planning - a largely neglected area in the literature on corporate strategy.

Traditional writings on corporate strategy tend to be self limiting in that they focus on a "single profit objective" and associated with this is the heavy emphasis placed on acquisition strategies in order to realize managerial profit objectives. The present study suggests that much more attention should be given to other than profit objectives, the conflict between them and their reconciliation. For this purpose a synthesis of the behavioural model of the firm and the managerial discretion model is proposed. The method uses four types of standards - historical, external, intentional and innovative - in setting multiple objectives at a target and at a constraint level.

In this target constraint approach the difference between the two levels determines a margin within which conflicting claims of multiple objectives can be reconciled and a consensus level can thereby be reached. The study shows that the existence of a gap between the innovative and the other standards signifies that growth will mainly come through technological change.

Theoretical aspects of technological change, in particular the economic and sociological approaches to diffusion of innovation are also discussed with special reference to the chemical industry. Against this background

a generalized growth pattern for basic chemicals is developed and this pattern identifies the competitive and innovative modes of growth. In the competitive mode the individual chemical producer seeks to increase the level of usage of his material in its established end use categories. In the innovative mode, on the other hand, growth is sought by innovating new end use categories.

Given a specialized producer willing to grow in his area, the competitive mode is characterized by the fact that marketing, financial and organizational measures can compensate for scientific and technological weaknesses, whereas intensive research and development activities are all important in the innovative mode.

The discussion finally leads to the formulation of a method of pinpointing technologically based opportunities. This method, the technological growth tree, is developed as a managerial tool for mapping out strategic opportunities for the chemical industrialist.

The tree consists of two principal branches, technological expansion and technological diversification, which subdivide into relevant strategies and tactics. Technological expansion strategies can be utilized in the competitive mode while the technological diversification strategies are appropriate in the innovative mode.

The usefulness of the technological growth tree, in particular its diversification strategies, is illustrated by reference to the bromine industry where application of the former has resulted in a number of potential opportunities. These require further research and development efforts for their realization. Resulting from this, the principles outlined in the present study can also be applied in other science based industries for strategic planning.

## ACKNOWLEDGEMENTS

I gratefully acknowledge the U.K. branch of the Friends of The Hebrew University of Jerusalem for their scholarship award to study at Stirling University. Acknowledgements are also due to the B'nai B'rith association for their complementary support.
This study could not have been completed without the untiring assistance and advice freely given by my supervisors, Professor D.H. Allen (Head of Management Science and Technology Studies) and Mr. R.W. Shaw (Senior Lecturer in Economics).
I wish to express my sincere thanks for the guidance received in their comments and during our many discussions.

Thanks are also due to Professor Gb. Cevidalli (The Casali Institute For Applied Chemistry - The Hebrew University of Jerusalem and Former Director of Research in Israel Chemicals Ltd.) for acting as my industrial supervisor.

It would be impossible to adequately acknowledge all those who have assisted in the development of this study. Therefore I would like to thank all those who have willingly given of their time.

In particular I wish to thank my friend Dr. G. Bethlehem (formerly a senior lecturer at the University of the Wittswatersrand, Johannesburg, South Africa, currently a senior official at the Israel Coal Supply Corporation) for the time he spent with me in many useful discussions.

Finally, I wish to acknowledge the friendly and inspiring atmosphere created by my friends and colleagues in the Departments of Management Science & Technology Studies and Economics of the University of Stirling.

TO:

My teacher the late Professor G. Stein (former Head of the Casali Institute of Applied Chemistry - Jerusalem) whose untimely death has been a great loss to all his colleagues, students, family and friends.

And also my supervisor the late Professor F.R. Bradbury (former Head of the Department of Management Science & Technology Studies - Stirling) whose support and encouragement will always be remembered.

CONTENTS

# CHAPTER 1

# INTRODUCTION

## 1.1 Objectives and Scope of this Work

This study attempts to suggest an appropriate conceptual framework for tackling growth and development in the chemical industry. It emphasizes organizational objectives and technological change as major forces shaping development in a science-based industry such as the chemical industry. Thus it is concerned with the direction of long-term strategic development but the detailed assessment of specific projects on the operational level is excluded. The broader objective is to stimulate a wider appreciation of the range of opportunities that should concern producers of basic chemicals.

In dealing with organizational objectives, the issue of social responsibility and the implications of its conflict with microeconomic objectives must be raised. Conventional corporate strategy literature tends either to ignore this subject, or at best, pays lip service to social objectives, relegating them to a secondary role, thereby avoiding the need of reconciliation of social and economic objectives.[1]

This is clearly an unsatisfactory solution, as social objectives cannot, for long, be assigned to a secondary role, particularly as the heavy chemical industry per force makes a major impact on the immediate environment in which it operates.

As regards development, it has long been recognized in the science-based industries, that growth and development depend on technological and scientific progress.[2] Yet, the conventional corporate strategy literature, notably Ansoff, has little to say in this context, and focuses its attention on acquisition strategies as the principal means of development. This exclusive concern with acquisition, limits the usefulness of traditional corporate strategy in a science-based industry. This study seeks, then, to contribute to the above inadequacies of corporate strategy in the real world.

The problem of reconciliating conflicting social and economic objectives is approached in the context of state-owned companies, a sector where legislation commits nationalized industry to social objectives. The question of growth and development facilitated by scientific and technological change is approached using the vehicle of the chemical industry, a well-established, science-based industry.

Being diversified, the chemical industry is involved in many sections of the economy, and though this creates difficulties in establishing end use categories, this, together with the emphasis on scientific and technological progress as well as overall environmental problems, makes the industry vulnerable to technological, economic and social uncertainties. Diversification and scientific basis can, however, be a source of strength and provide growth opprotunities for the industry.

Coupling trends of increasing importance of social objectives (as expressed in increased governmental involvement in industry) with the special characteristics of the chemical industry create complex problems of compatibility of political aspirations with what can be seen as technologically possible and economically feasible.

The study suggests that the complex nature of such real world problems, where it is impossible to reduce at will the number of degrees of freedom of the studied system, discourages the exclusive use of a theoretical scientific approach. Nevertheless, it should be recognized that a theoretical approach may be valuable in gaining a better understanding of the process of growth and development in the chemical industry. An intermediate approach, which combines some theoretical treatment with empirical study is then proposed.

Chapter two commences with a concept of corporate strategy. Two basically different schools of thought are identified in the corporate strategy literature. One, referred to as the formal approach,[3] supports systematic strategy formulation. The other, sometimes called the informal approach,[4] argues that due to real world complexity and limited human capabilities, it is impossible to systematically formulate corporate strategy. The issue of the general applicability of conventional corporate strategy methods raises the question of their relevance to strategic planning in the chemical industry.

Chapter three deals with organizational objectives and raises the issue of conflicting objectives in a multiple objective firm with the firm's microeconomic objectives. The chapter proposes a simple, practical method for balancing conflicting social and economic objectives. Four standards, viz. historical, external, extrapolative, and innovative, together determine the eventual balanced objective function of the organization.

The existence of a gap between innovative standards and intentional standards signifies that growth will mainly come through technological change.

This point is illustrated in Chapter four by applying the concept to a specific industry - in this instance that of the bromine industry and an individual bromine producer in particular. The chapter points out that traditional strategies can contribute little to aiding the latter in attaining its objectives. The chapter concludes that there is a need for a different approach which seeks to change technological circumstances and maintains that only strategies relying on technological change can meet the challenge.

Chapter five discusses some theoretical aspects of technological change with special reference to the chemical industry. The conclusions arrived at could be of some assistance in structuring suitable strategic options. Identification of the relevant strategic options raises the problem of mapping out and defining development opportunities for the chemical industrialist.

Chapter six proposes a simple conceptual framework in the form of a growth tree which outlines growth and development directions for basic chemicals. The chapter illustrates the application of the above conceptual framework by using the example of a bromine producer. The results of this study identify a number of new areas of research with potential opportunities for product development.

Chapter seven briefly reviews the conclusions of earlier chapters and emphasizes the main points.

We commence then, with an evaluation of the current climate of corporate strategy.

# CHAPTER 2

# THE GENERAL APPLICABILITY OF CORPORATE STRATEGY

## 2.1 Concept of Corporate Strategy

There are many definitions of strategy which may be the result not so much of basic disagreement as semantic differences. Examples of some formulations include the following:

1. "Strategy is a set of goals and major policies."[1]
2. "Strategy is a rule for decision making."[2]
3. "Strategy planning is concerned with both formulation of the goals and the selection of the means by which they are to be attained."[3]

From these and other definitions it is clear that corporate strategy is concerned with the systematic formulation of objectives together with assessing alternative means for achieving them. The primary interest is in the process of, and in identifying the need for, strategic decision in concrete instances.[4] A strategy should therefore become the firm's responsive framework for interaction with the environment. The importance of responsiveness stems from the possible intervention of major surprises which may require a reordering of priorities in specific situations facing management.

The intervention of unforeseeable events together with other factors strongly questions the feasibility of using a systematic approach to strategy formulation. This is the essence of corporate strategy and the focus of this chapter.

## 2.2 The Main Approaches to Corporate Strategy

There is a plethora of books and articles on the subject of corporate strategy. Nevertheless, an analysis of the literature shows that besides semantic differences and the placement of emphasis, two basic schools of thought can be observed; the first, often referred to as the informal school, argues that strategy can not be made explicit, since organisational complexities, poor data base and limited human capabilities prevent the feasibility of systematic strategy formulation. The other school of thought, known as the formal school, argues that in the face of complexity, changes in environment, scarce information and uncertainty, only a systematic approach can assist management in its tasks.[5] This formal approach as exemplified by Ansoff and others is reviewed below.[6]

## 2.3 The Formal Approach

### 2.3.1 The Ansoff Model

Ansoff[7] has developed a comprehensive model where corporate strategy is dominated by the decision to choose the product-market position of the firm. The strategy is formulated through an 'adaptive search method'. Essentially this is a continuous review process of objectives and resources in the face of a changing environment. Reviews are 'triggered' either internally or externally and end up in adaptation of objectives. The starting point is the need to distinguish between the major factors affecting management's behaviour: objectives, responsibilities and constraints.

Objectives are defined as decision rules which are management's aid in guiding and measuring the firm's performance. Responsibilities are described as obligations undertaken by the firm which do not interfere with the firm's internal guidance and control mechanism. An example could be an annual donation to some charity fund for public purposes.

Constraints are decision rules which exclude certain options from the firm's range of activities, but are not concerned with the firm's choice of product-markets in strategy formulation. Therefore, responsibilities and constraints belong to the same category representing the limits within which the firm must operate, whereas objectives are the goals that the firm attempts to achieve. Thus, responsibilities and constraints have to be taken into account before objectives can be formulated.

The central interest of the Ansoff model is the product-market position of the firm particularly emphasizing acquisition as a means of diversification and expansion (expansion is used here in Ansoff's narrow sense, i.e., growth in same product-market), acknowledging the higher synergy attached to the latter. However, even in the general business context (and more so in the public sector context), the model may be criticized for being too centred around the profit objective (as expressed as return on investment or ROI) and paying too little attention to the role of social objectives and other constraints.

The contention that profit (satisfaction of stockholders' needs) is vital for renewal of resources that ensure the firm's long-term survival, cannot be refuted, but the stakeholder theory maintains that a firm ought to pay attention to other interest groups which Ansoff relegates to a secondary position. For example, in the contemporary clash between management and labour, employees organized at all levels in the firm could threaten the firm's survival, just as public opinion can through legislation, in as much as a poor profit performance can, by laying the firm open to predators through acquisition or merger. The Stakeholder concept recognizes ROI as one objective whereas Ansoff gives it the dominant role. But there is no reason why stockholders will be given predominance over employees or the public interest.

Another weakness of the model is that is pays no attention to social forces within the firm which has to adopt to change and lacks a mechanism for working out social problems posed by change. However, bearing these limitations in mind, the model may be valuable as an aid to management interested in formulating acquisition strategies.

### 2.3.2 The Argenti Model

A more recent work advocating the formal approach to corporate strategy has been put forward by Argenti.[8] Argenti starts from identifying three types of objectives: Purpose, Ethos, Strategy. The purpose of any organization is to generate a specific benefit for a specific group of people; ethos refers to the manner in which an organization behaves towards other people while generating this benefit; and strategy refers to the means the organization chooses in achieving it.

However, the difference between Argenti and other authors is mainly in nomenclature. What Argenti defines as purpose is usually described as objectives; ethos in fact is responsibility and constraints; and Argenti's strategy is commonly referred to as means. Thus the distinction between purpose and ethos is similar to Ansoff's distinction between economic and non-economic objectives. Like Ansoff, Argenti emphasizes economic objectives as the main concern of the firm since he regards the shareholder as the sole intended beneficiary of most companies; whereas ethos has a secondary effect on the firm's behaviour while generating the benefit. Argenti recognizes that if an organization has several equally important beneficiaries, difficult reconciliation problems result. Therefore, in developing his model he confines his analysis mainly to the economic objectives.

The essence of his model can be represented by the following sequence of steps:

(1) Decide purpose and select target

(2) List major ethological (non-economic) targets

(3) Make an internal and external appraisal

(4) Decide strategic structure

(5) Select operational objectives

(6) Monitor

(7) Revise targets and strategy when necessary.

In his model Argenti introduces the concept of strategic structure, challenging Ansoff's limited concern with product-market strategy. According to Argenti, there is an optimal combination of factors (strategic structure) which affects the way in which purpose and ethos (or objectives and constraints) are to be satisfied. These factors are markets, products, physical facilities, services, finance, employees, supplies, distribution and management. Argenti realises that there is a range of strategies pertaining to each of these factors resulting in an almost infinite number of possible strategies. Therefore, he suggests that strategic structure will be selected first and this will determine the choice of relevant strategies.[9] The main proposition is to select a strategic structure through a formal decision-making process. Thus product-market strategy, which is the focus of Ansoff's treatment, becomes a component in Argenti's analysis. The latter pays more attention to the need to introduce some organizational changes before attempting to accommodate corporate planning within a firm. He therefore suggests a simple social adaptation mechanism, to enable members of the organization to cope with difficulties posed by change. Although the revised model represents considerable improvement compared with earlier ones,[10] there are still two weaknesses. One is its preoccupation with so-called mechanistic organizations where all decision-making power is centralized and the flow is from top to bottom.[11] The second weakness is the little attention given to non-economic social and political linkages to the environment, which Argenti has difficulty in reconciling.

## 2.4 Informal Approach to Business Strategy

After reviewing the main advocates of a systematic rational approach, we turn now to the opposite view. This was first expressed by Lindblom[12] who asserts that the formal approach is impractical except for the simplest problems. The argument put forward is that organizational and environmental complexity, uncertainty of information, and limited human intellectual capacities make a rational comprehensive model virtually impossible.

Lindblom's approach is based on positive analysis and mainly founded on observations of decision-making processes in political institutions where strategy formulation proceeds in an adaptive, informal, but unsystematic way. Lindblom suggests a methodology which he terms 'successive limited comparisons' or the 'branch' method, as opposed to the formal approach to corporate strategy, hereunder referred to as the root method.

Five controversial points distinguish the branch method from the root method. According to Lindblom, there is no clear distinction between value goals and the accompanying empirical analysis as to how these may be achieved. A prerequisite in the formal root approach is that goals are clarified ab initio before strategies for achieving them can be formulated. Following from this, Lindblom maintains that due to the simultaneous evolution of objectives and policies, means-ends analysis is not necessarily appropriate, whereas in the root approach means are selected and assessed in the light of predetermined ends.

The root method places emphasis on optimizing whereas with the branch method satisficing is all important. Thus strategy finally selected is not necessarily an optimum - the criteria are feasibility and acceptance by all decision makers. In the formal approach the success of a strategy is evaluated by the degree to which objectives have been attained. Implicit, therefore, in the approach is the understanding that objectives can be specified independently of strategy itself.

With the emphasis on satisficing, the level and complexity of analysis is drastically curtailed. In this context, Lindblom suggests that limits on human intellectual capacities and on available information set definite limits to man's capacity to be comprehensive. Therefore, every decision maker faced with a sufficiently complex issue is compelled to simplify. Thus policy comparisons are limited, directly reducing the number of alternatives to be evaluated. This results in a reduction in the various courses of action under consideration. However, in the business context, it is by no means clear whether such an approach is acceptable. Simplification by neglecting different strategic alternatives can result in rejection of highly beneficial projects and leave the firm vulnerable to take-over bids. The diversification alternative is a typical example in this instance.

The formalists, of course, require a 'comprehensive' all-embracing analysis and consideration of every important factor. This in turn necessitates heavy reliance on theory. In the informal approach, however, planning is based on successive limited comparisons rather than proceeding according to a priory theory. The latter is therefore the antithesis of the formal approach.

Lindblom criticizes the formal approach which relies on theory on the grounds that in most social areas adequate theory is simply not available. This observation is not strictly true, however. Depending on the degree of uncertainty, it is nevertheless possible to develop models that represent real situations. Model building and data collection lay the first foundation for theoretical development. And given a body of knowledge, theory becomes the most systematic and efficient way of applying that acquired knowledge to a specific relevant problem. There is clearly room for theoretical model building in business planning.

To sum up, it is clear that the branch method is pragmatic as is evident from its wide application in many organizations. It is particularly useful to institutions consisting of coalitions and subcoalitions of groups and individuals who share some aspirations which are more significant than their conflicts (such an organisation proceeds through what Cyert and March[13] called 'quasi resolution of conflict', avoidance of undertainty, problem-motivated search and organizational learning). Clearly, the branch method, through incremental changes, is most suitable for this type of organisation.

The acceptance of a policy on the basis of agreement and feasibility provides a useful social adaptation mechanism to elevate personal and interpersonal problems and threats posed by change. The requirements of the branch method on the organizational resources such as finance, time and technical know-how, are less demanding than those of the formal approaches, which make it more simple to use. However its adherence to past policies (as a base for incremental changes), reluctance to use theory and consequent reliance only on readily available know-how, make it inadequate for organizations which are development and growth oriented.

## 2.5 An Integrative Approach

The two principal approaches reviewed so far have both advantages and disadvantages. It seems that in practice the above-noted advantages of simplicity and ease of application made the branch method more applicable than the formal approach. This was confirmed in a fairly recent study by Eliasson that surveyed several American and European companies.[14] The study pointed out that relatively minor effort is spent in comprehensive planning to foresee and prepare for major decisions and changes. Formalized planning, where and if observed, was mainly applied to repetitive decisions under relatively stable environmental conditions. The apparent success in managing major change in many large firms must therefore be attributed to factors other than the formalized comprehensive planning system. Eliasson's suggestion that the observed ability to cope with major changes largely depends on the individual capabilities of each particular manager seems convincing, but need not invalidate a systematic rational approach. After all, strategy should be no more than the systematic and explicit application of what managers are doing intuitively and often implicitly.

Ansoff[15] has also recognized that 15 years of experience has shown that it is difficult to make strategic planning applicable in practice. In analysing the reason for this, Ansoff concludes that in strategic change, when the firm shifts its attention from existing linkages with the environment to creating new linkages with the environment, each of its major characteristics: objectives, values, management, structure, etc. are transformed. Therefore strategic planning which focuses on matching existing capabilities with opportunities is only one aspect of the whole picture. To adapt to change, appropriate capabilities must be developed. Lack of the desired capabilities will result in 'resistance to planning'. Though planning for change is a cognitive-logical process, it also poses some socio-psychological problems. Hence, to accommodate change within an organisation, some sort of social adaptation mechanism such as the branch method is needed.

The superior logics of the formal approaches and the superior social adaptability of the branch method, clearly suggest the need for a balanced approach. Ackoff[16] indeed proposes a similar approach in his philosophy of planning that emphasizes learning as more important than the resultant plan. Ansoff also picks up this point which he refers to as 'planned-learning'. He identifies three major points of departure from current formal approaches. The first one challenges the assumption that planning must always precede action; secondly, it recognizes the limited value of forecasting, since the residual uncertainty usually contains major surprises which may greatly affect the firm. Thirdly, the choice of the sequence of change in the firm's strategic posture is not left to the arbitrary setting of priorities, but will be determined through diagnosis of the firm's need to change and the required degree of change.

The main characteristics of the planned-learning approach were used by Christensen and others[17] in developing a simple general approach to strategy formulation. They suggest that the limitations on the concept of strategy due to the inherent difficulty of conceiving a viable ends-means pattern, do pose problems, but these are not insurmountable.

The learning process of arriving at a strategy involves the following questions that can regularly be asked:

1. Is strategy identifiable and clear either in words or practice?
2. Does strategy fully expoit environmental opportunities?
3. Is strategy consistent with corporate competence and resources, present and projected?
4. Are major provisions of strategy and the program of major policies internally consistent?
5. Is the chosen level of risk feasible in economic and personal

terms?

6. Is strategy appropriate to personal values and aspirations of the key managers?
7. Is the strategy appropriate to desired level of contribution to society?
8. Does the strategy constitute a clear stimulus to organizational effort and commitment?
9. Are there early indications of responsiveness of markets to strategy?

Akin to advocates of the formal school, Christensen et. al. pay only lip service to non-economic objectives and social responsibility. The questioning procedure above ignores most of the stakeholders, only top management is considered. Further, the firm is concerned with the greater environment not only its immediate markets.

Nevertheless Christensen et. al.'s approach represents an early practical approach to combine the rational/formal and the political/social approaches to strategy formulation. Later, Ansoff[18] conceptualized this combination in his planned-learning approach, mentioned earlier in this chapter, which eventually led to the system of strategic management.

Strategic management has recently been identified by Hoffer[19] et. al. as the new paradigm for strategy studies. They regard strategic management as the overall concept involving: (1) goal formulation (2) strategy formulation; (3) strategy evaluation; (4) design of macro-organizational structure and systems; (5) strategic control.

Hoffer et. al. argue that the strategic management paradigm addresses itself to unattended problems of earlier strategy writings such as the conflict between Chandler and Andrews' view that strategy comprises both means and ends and Ansoff's view that ends and means should be separate.

In distinguishing processes (1) and (2) above strategic management clearly supports Ansoff's view. Other problems include: strategy as a means to integrate various internal functions and the firm with its greater environment; distinction between various levels of strategy and the need to attend to organizational and managerial processes for managing strategy.

These problems are addressed in the strategic management paradigm through the processes above. Thus, the process of strategy formulation tackles the problem of integration by proposing several strategy levels such as societal, corporate, business and functional strategies which answer questions about the nature of corporate governance, political involvement and the set of businesses to be in.

The strategy evaluation process is associated with the assessment of future impact of strategy on overall organizational performance.

Finally, the strategic control process answers questions such as: is the implemented strategy the intended one? and, are the results produced those which were anticipated in the strategy evaluation process?

Although the strategic management paradigm is more comprehensive than its predecessor, in the sense that it covers a wider range of issues, it still does not attend satisfactorily to the problem of explicit trade-off between social and economic objectives and tends to relegate the former to a secondary role. Also, the formal/rational and social/ political approaches in the strategy formulation process has not yet been satisfactorily amalgamated.

Recent attempts towards such amalgamation have been made, for instance, by Mitroff and Mason[20] and by Wissema et. al.[21]

Mittrof and Mason propose dialectical inquiry as part of a strategic assumptions surfacing and testing (SAST) technique, as a useful aid for strategy formulation. SAST comprises the following steps:

(1) assumptions specification; (2) assumptions negation and generation of counter strategies; (3) assumptions integration and (4) composite strategy formulation.

In the authors' assessment the strength of their procedure lies in the "comprehensive consideration of multiple stakeholders plus critical planning assumptions."[22] They argue that such an approach requires both behavioural and financial (analytical) data. It is not clear, however, how these two types of data are going to be integrated - this issue seems to be left to the potential users to decide.

A more explicit procedure in this respect has been proposed by Wissema et. al.[23] Theirs combines a management development plan with overall strategic planning. The former constitutes the social/political factors, the latter - the formal/rational factors. In fact, it should be noted that the conceptual basis of this methodology is similar to that of Christensen et. al. and therefore open to similar criticism (see p.15).

So far we have been concerned with the strategic management system, but another contemporary concept - that of strategic issue management (SIM) is also worth noting. Ansoff[24] defines a strategic issue as any forthcoming trend which is likely to affect the achievement of corporate objectives. SIM is a systematic procedure for early identification and fast response to strategic issues.

It should be noted that in principle SIM resembles the strategic management system. It postulates shorter time horizons, and therefore can be considered as complementary to periodical planning, but not as a substitute. SIM, closely related to strategic management, suffers from similar shortcomings and is liable to similar criticism.

## 2.6 Interim Conclusion

It has been noted that the conventional corporate strategy literature pays only lip service to non-economic objectives and social responsibility.

Traditionally, big business has never really been concerned with or committed to social objectives. The growing public awareness of the dominancy of a few major industrial corporations has caused management to examine these issues. The present study examines the characteristics of state owned companies in order to understand how social responsibility influences the process of strategy formulation. Nationalized industries are traditionally associated with social responsibility (more sensitive to the public interest).

A major shortcoming in the literature as reviewed above is the heavy reliance on traditional analysis that emphasizes financial strategies for the realization of growth objectives. However, there is a body knowledge in the literature that recognizes the important role of technology in shaping business growth.

In the following sections, therefore, the characteristics of state owned enterprises and their approach to the strategy formulation process is discussed as well as the technology based approach to business strategy.

## 2.7 Strategic Planning in the Public Sector

The similarities of state-owned and privately-owned firms are fairly obvious; both are goal directed organizations ftransforming inputs of resources into goods and services. However, there is a basic distinction between the two, namely regarding accountability and control, which is the source of other differences. The most important of these is the question objectives which will be dealt with in Chapter three.

As far as accountbility and control are concerned, boards of directors in the private sector are formally accountable to their shareholders. Though it should be noted that in the large public listed companies, where shareholders are widely dispersed, there is a distinction between ownership and control, whereas in the small, tightly held companies these two concepts merge. Nevertheless, in both instances the board of directors is appointed by the shareholders in general meeting.

In the state-owned company, however, as a recent study has shown, the decision whom to appoint to the board is in the hands of a Minister of State.[25] Such ministerial appointments reflect government involvement in the public sector companies. Moreover, from a more recent study by Mazzolini (covering Italy, France, U.K. and other countries), it can be concluded that this intervention of the executive authority may often lead to the intervention of the legislative authority in the form of parliamentary control.[26] Indeed, in the U.K., for example, a NEDO report has argued that governmental involvement in the strategies of nationalized industries is a necessity because of the economic and social implications of their actions for public policy. These often are so complex and politically sensitive, that they cannot be left to management alone to determine.[27]

This governmental involvement may have both advantages and disadvantages when compared with a private sector firm. As is evident from the above-mentioned NEDO report, there are additional levels of decision-making in the public sector which are made up of ministers and of members of parliament. On one hand, it may be argued that additional levels of decision-making can complicate the strategy formulation process to a considerable extent; but on the other hand, political control of state-owned companies may result in responsiveness to societal needs which can seldom be found in the private sector.

It should be noted, however, that the social awareness of politicians tends to be biased by short-term considerations such as elections, whereas strategy formulation is concerned with the long term.

The sensitivity of politicians to public opinion in democratic societies, coupled with short-term considerations, may be responsible for their tendency to avoid long term projects with no immediate pay-offs. This may inhibit long-term strategic decisions of top management in the public sector, when compared with firms in the private sector.

On the other hand, as Mazzolini notes, governmental involvement and support often implies access to sources of finance on a grand scale and favourable terms which usually are not available to similar firms in the private sector.[28]

Finally, there is an additional legal constraint on strategic planning in the public sector. That is, a state-owned company is obliged by law to operate in a specific area. On the other hand, it is generally accepted that a private sector firm has the freedom of action, for example, that when faced with a falling demand for its products may make moves towards diversification.[29a] It should be noted, however, that this general belief should be qualified, as the example of the Sherman and Clayton Acts in the U.S.A. which have sharply limited the freedom of action of diversification of many private sector firms, has shown.[29b]

There are several major differences between state-owned companies and privately-owned firms which stem from the direct political control of the former. These are:

1. Greater social awareness.
2. More levels of decision-making.
3. Greater access to sources of finance.

4. A stronger obligation to operate in a specific area.

In conclusion, it is clear that direct political control can be a potential source of both strengths and weaknesses for the state-owned company. In the final analysis it depends upon the skill of top management and the political establishment whether or not the strengths will prevail over weaknesses. In principle, therefore, the problems of strategy formulation in the state-owned firm should not differ from those in the private sector, and this implies that methodologies developed and lessons learned in one sector should be applicable to the other.

## 2.8 The Technology Based Approach

Recognition of the important role of technology in shaping business growth is not new, however, even until recently it has not been fully exploited. Indeed, Roberts notes that "most corporations have ignored technological strategy as an element of overall corporate strategy. For some reason, most firms limit their attention to financial and marketing strategies and planning, ignoring technology as a major area for assessment, planning and strategic development".[30] Much earlier, Quinn[31] already observed that "many managements do not recognize that in organizing the company's resources - a growth through research strategy must be backed by entirely different kinds of financial and organizational commitments from more conventional market development or acquisition strategies".[32]

This is because the research approach requires longer time horizons and ability to cope with higher risk. Although Quinn realizes that management attitudes determine the research mission (i.e. if it is to be the dominant growth strategy or would simply service present activities), he asserts that in a dynamic technological environment, present products - plus planned acquisitions are unlikely to fulfill all corporate objectives.

Both applied and fundamental research will be required to achieve objectives (see Figure 1). Applied or offensive research is characterized by identification of market needs and then working back to sequential programmes to meet these needs. In fundamental research - promising scientific areas are pinpointed which may provide the foundations for new product developments. Market needs are presumably identified by the marketing function, but the identification of promising research areas is more problematic.

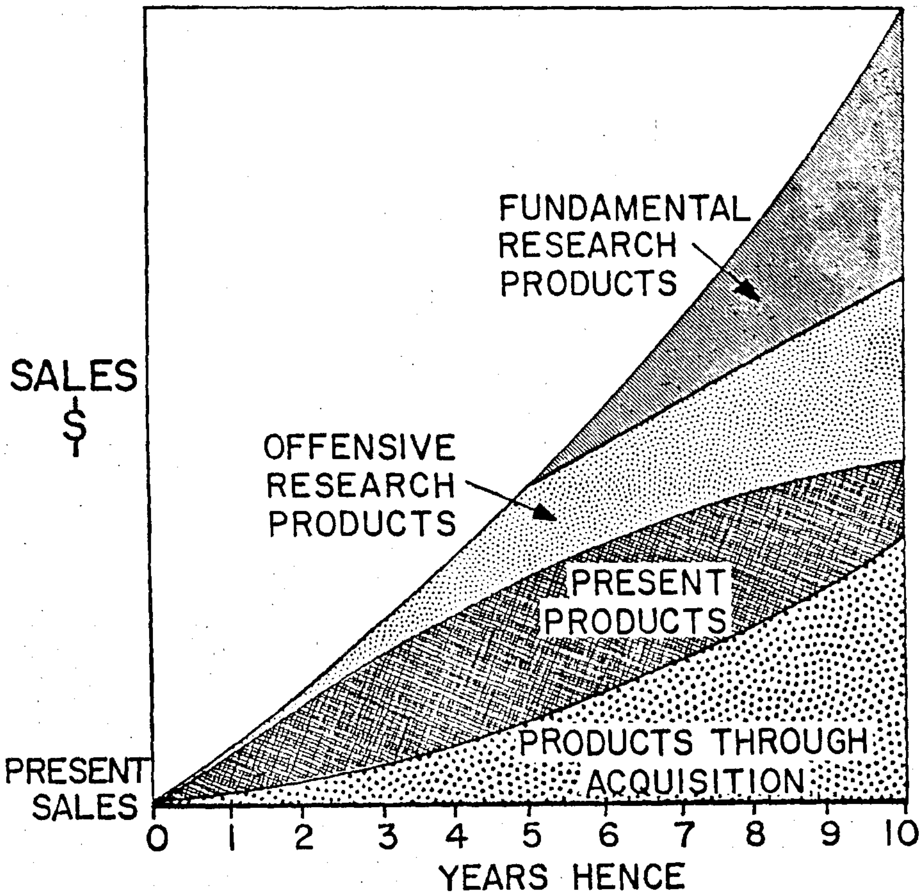
Quinn assigns this task to the individual researcher without any criterion or methodology. He only proposes a tight control and reporting mechanism which arouses doubts about its ability to facilitate creativity. Another obvious deficiency, is his neglect of the important possibility of growth through acquired research (e.g. licensing)[33]. Nevertheless, the value of his approach lies in the early attempt to consciensciously integrate corporate planning with R&D planning.

The approach has been elaborated on further by Twiss who argues the case for mutual influence of R&D and corporate strategy.[34] He asserts that "failure to translate the corporate plan into decision making at all levels will nullify its purpose. Yet there is a great deal of evidence to suggest that this occurs frequently, particularly in relation to investment in technological innovation".

This failure stems from the two most common objections to application of formal planning to R&D. One rests on the fact that many major innovations originate by chance (serendipity), and the other argues that the scientific spirit of free inquiry must be given satisfaction in order to maintain creativity.

Admittedly, both serendipity and the need for personal research cannot be ignored. But they should not invalidate planning if the latter

Figure 1




Source: J.B. Quinn op. cit. p. 194.

is flexible enough to accept some activities which are not directed towards clearly identified ends. Twiss argues that this flexibility can be achieved if the company is viewed as being engaged in two types of business - one defined by the conscious process of strategic planning, and the other based upon utilization of random discoveries. Successful research and development projects of the first type are readily related to the corporate plan, whereas those relying on random discoveries, may be divided into three categories:

(i) random discoveries which are compatible with the formal plan;

(ii) highly promising, but unrelated projects which may require strategic change;

(iii) unrelated worthwhile projects, but not promising enough to justify the required cost of strategic change. These can be licensed to others.

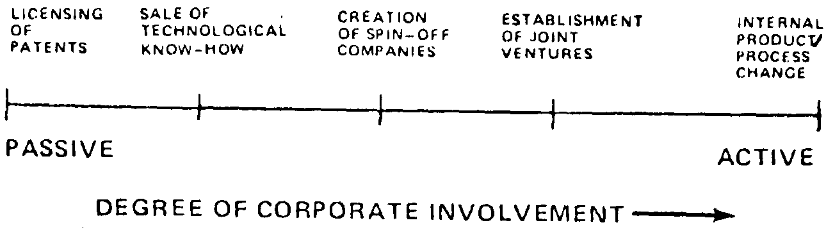
Twiss recommends extending the rationale behind category (iii) and deliberately channel additional funds into developing the new technology for the sole purpose of licensing.

But the effectiveness of licensing is questioned by Roberts.[35] Roberts presented data which indicate that patent licensing and even direct sale of technological know-how, seldom provide attractive income to the technology developing firm, and he concludes that:

(1) Large firms should have relatively little interest in passive strategies, with least interest in the licensing of their own patents to others. This view is shared by Stumpe who, due to his experience in Rexnord, also prefers the active strategies.[36]

(2) Other alternatives of technology utilization are therefore suggested by Roberts. These are ordered by a degree of corporate involvement (see Figure 2).

Figure 2: Alternative technology commercialization strategies.




Source: E.B. Roberts, op. cit. p. 24.

Nevertheless, acceptance of these criticisms does not have to invalidate the "two businesses" notion of Twiss, that can increase the number of alternative strategies for projects in category (iii). In this extended form the "two businesses" notion enables the requirements of corporate planning to be reconciled with the realities of the R&D situation. While provision has been made for utilization of the unexpected, it is still brought within the bounds of corporate control.

Having established the compatibility of R&D with formal planning, there remains the need to relate a critical technological decision to the corporate plan. Twiss suggests doing this by a carefully formulated R&D strategy. The formulation should be carried out in the same formal approach as corporate strategy. It should therefore involve analysis of environmental trends and a systematic internal appraisal of the R&D department. Several strategies are available:

Offensive strategy - first in the field with a technological innovation. This strategy tends to be utilized by either the small innovative company or a large market leader wishing to protect its position.

Defensive strategy - involves less risk as it follows technological successes of others.

Licensing - an absorptive strategy - presents opportunities through the purchase of R&D results of others.

Interstitial strategy - is essentially an attempt to find a niche in the market in order to avoid direct confrontation with competition.

Maverick strategy - is actually the application of a new technology in an established field. The market leader is thus vulnerable to the new technology and is unlikely to introduce it. This provides an opportunity for a newcomer to the field.

Acquisition - an alternative to licensing is to acquire key staff of the licensor, its complete project team, or even the licensor itself through take-over or mergers.

The research strategy formulation consists of the selection of the appropriate strategy or combination of strategies that follows environmental analysis and internal appraisal.

The value of the approach of growth through research lies in the fact that science based industries must grow and develop as a result of technological change. Nevertheless, it is worth noting that the pressing problem that emerged in a recent conference on innovation and corporate strategy was "not the lack of supply (of innovations) but the inhibitions of an organization to take advantage".[37]

The present study suggests that strategy formulation cannot be dissociated from the specific industry or even company for which it is intended. To this end the chemical industry is chosen as a well established and generally recognized science-based industry in the context of which strategy formulation may be fruitfully discussed.

## 2.9 The Special Case of the Chemical Industry

### 2.9.1 Introduction

The chemical industry has its foundations in the 19th century when traditional inorganic chemistry was applied to produce simple reactive intermediates that served as inputs for other industries. Today, as a result of significant technological advances, the chemical industry has changed vastly. The traditional discipline has been enriched with the application of sub-disciplines such as physical, organic, polymer and bio-chemistry. The result is that today there exists a whole range of chemical sectors and sub-sectors, which are collectively referred to as chemistry-based industries.

An example of the direct application of scientific research and development alluded to above is the plastics industry where in the production of PVC there has developed a whole range of products for the electrical industry; e.g., PVC provides durable, non-toxic electrically resistant material for electrical sheathing.[38] Thus, the chemistry-based industry has developed from the production of simple chemical compounds to the production of complicated molecules that are used in virtually every modern day application.

There are a number of distinguishing characteristics of chemistry-based industries and each in its own way affects the above-mentioned progress. The present chapter directs itself to the need for systematic strategy formulation in a sector subject to special circumstances. These are considered below:

1. R & D activity
2. Raw materials
3. Environmental awareness
4. Cartelization.

### 2.9.2 The Problem Associated with R&D Activity

The great problem, and indeed challenge facing the science-based industries is breaching the gap between R&D and product launch. In particular, there are two significant stumbling blocks:

(a) the degree of technological uncertainty associated with R&D projects, and

(b) the problem of market development.

Technological uncertainty arises because of unanticipated technological difficulties that require some new scientific knowledge to resolve them. In extreme cases, such technological difficulties may lead to total failure of an R&D project, even if that project has had an ex-ante high probability of success.

In order to appreciate the importance of the issue, consider for example the study of Mansfield and Brandenburg[39] based on 70 R&D projects conducted by a leading electrical equipment manufacturer.

Out of 70 R&D projects, 70% had an ex-ante high probability of success and less than 3% had a fifty-fifty chance. However, ex-post it was found that 44% were fully successful technically and 16% were unsuccessful due to unanticipated technical difficulties. Scherer suggests that this experience is representative of successful industrial R&D in general, and indicates that firms attempt to commence R&D projects only after the principal technical uncertainties have been reduced by inexpensive internal or externally conducted research.[40]

But mere technological breakthrough is not enough for achieving overall success in an R&D program. Appropriate market development is also required. This is because planning gaps between innovation and product development and/or environmental changes may result in failure of a technically successful project.

Clearly, the problems involved in both reduction of technological uncertainty and appropriate market development, require comprehensive strategic planning. This implies a corporate strategy coordinated with R&D which capitalizes on the latter's developmental opportunities. Indeed, some authors, notably Neil Chamberlain, assign the major role of setting alternative goals for the firm to the R&D function.[41]

A principal problem in strategy formulation in this context is screening of alternatives. This can be achieved in two ways. One suggests choosing a predetermined direction to a specified goal. This saves money and time; however, the main disadvantage is its inherent rigidity and dependence on the preselected course of action.[42]

The second permits a shift in goals and avoids establishing specific characteristics of the final result. Its main advantage is extreme flexibility at the outset while leaving increased rigidity to the final stages. In general, its disadvantages are high costs in terms of time and money.[43] The chemistry-based industries minimize these disadvantages by the use of the chemical laboratory as the tool of research. The chemical laboratory offers an efficient and economic way of testing and screening many alternatives at an early stage.[44]

The literature cites examples where several thousands of compounds were screened per each new product that was introduced into the market. A case in point is that of the bipyridyl herbicides.[45] An overall target to develop a herbicide possessing selective activity, applicable to either foliage or soil was formulated. The search was based on the hypothesis that quaternary ammonium salts with a specified structure would be the most powerful scorchers, and therefore the best weedkillers. Many ammonium salts were tested and the chemical screen had been refined from the general class of quaternary ammonium salts to bipyridylium salts, and within this class to those compounds possessing a particular physical property - a certain range of redox potential. Finally, two compounds were singled out as successful candidates for future development.

The evantual success of this and other examples supports the assertion that it is possible to test and screen chemical R&D projects at an early stage with a high degree of confidence,[46] and this can be achieved economically and efficiently by employing the chemical laboratory as a "mini-pilot plant".

### 2.9.3 Chemical Raw Materials

The application of chemical scientific knowledge provides the means not only of producing a whole range of products from relatively few raw materials, but also of inventing alternative production processes using different starting materials for producing the same final product, or even inventing a new final product.

These two inventive activities represent the most demanding applications of chemical R&D activity just discussed. The case of terylene illustrates how raw material availability affects a new product development. Terylene was invented in Britain but the limited supply of ethylene glycol and paraxylene impeded the large-scale manufacture of the material. In the U.S. these raw materials were readily available and hence large-scale production started there.[47] It is interesting to note, however, that introduction of terylene became later an incentive, and triggered the development of an elaborate process for favouring yields of paraxylene over other isomers, thus providing the necessary raw material. This shows how the ability of chemicals to react differently under different conditions affect industry development, and problems of availability can be overcome if careful strategic planning triggers development of alternative processes for producing the raw material for any new product launch.

### 2.9.4 Environmental Awareness

Another problem facing the chemical sector is the growing public awareness of the environmental hazards posed by the industry. The pollution may take several forms:

1. Effluent from day-to-day industrial operations causing air, marine and river pollution.
2. Hazardous products - e.g., persistent pesticides such as DDT.
3. Potential of serious accidents, e.g., Seveso.

Growing awareness of these hazards has a significant effect as legislation bans certain products and increases production costs of others by setting rigorous conditions of manufacture. Also, due to the interdependence of chemical products, a ban on one may affect others.

In these circumstances, the role of strategic planning is to respond to the public awareness and to overcome the environmental hazards associated with the chemical sector, by proposing safe products and production processes.

### 2.9.5 Cartelization

The chemical sector is typically characterized by high capital intensity. This tends to result in high market concentration; that is, few large firms control a large share of the market. Capital intensity, market concentration and the fact that chemicals are usually marketed internationally, clearly allows for the organization of the chemical industry into national and international cartels. Generally, cartels are meant to provide price stability. Thus Learned[48] rightly sees a strong incentive for the larger firms to protect themselves against breaks in the price structure as a result of excess capacity, thereby maintaining high contributions towards fixed costs. There is also the need to counter competition resulting from the ease of entry into markets for undifferentiated basic and intermediate products and cartelization facilitate this inhibition of competition.

Concerning technological stability, the case is not so clear cut. Some authors regard cartelization as a barrier to technological change, whilst others see it as an incentive. Learned contends that cartelization in the chemical industry is intended to shield the industry from rapid technological change and thereby and in this way ensure stability. However, Learned gives little evidence to support this view. This view is also held by Fellner who a priori would expect competitive producers to adopt new cost reducing innovations more rapidly than monopolists, other things being equal.[49]

In contrast, Salter has pointed out that the relationship:

marginal revenue - total costs of marginal new capacity = operating costs of marginal existing capacity,

under profit maximization, reveals no reason for a greater delay in introducing new techniques to monopolistic industry compared to competitive industry.[50]

In his analysis of product innovations Scherer[51] assumes:

(i) Participants behave in a profit maximizing manner.

(ii) Imitation in kind is feasible (i.e. patent barriers can be surmounted).

(iii) Each participant must carry out its own R&D to market its improved product (i.e. no licensing).

Under these assumptions Scherer has found two contrasting influences of market structure. On the one hand, competitive market may enhance new product development, as the probability of new product development increases with the number of producers in the market. Due to competition, the first innovator will stimulate others to follow suit. On the other hand, if this trend continues beyond some point, given a certain profit potential, the more producers there are the smaller the profit share of each. Therefore each producer may postpone initiation of Research and Development effort in the fear that rapid imitation of his new product by others will eliminate its innovative profits.

Although assumptions (ii) and (iii) above are not realistic, the controversy regarding the influence of market structure on the rate of innovations clearly indicates that the latter is not the only factor among the forces determining technological development. In fact, the present study suggests that the dominant determinant of industrial growth and development is the technological basis of the industry concerned.

To summarize, the market structure of the chemical industry has developed from one of high concentration, because of the high capital intensity of the industry, to the next logical step, viz. that of cartelization of the industry. For it is argued that only in this way can a semblance of stability be maintained in an industry which operates in a rapidly changing technological environment. This in itself is a destabilizing force resulting from the on-going R&D taking place. Thus, in a world where change is the dominating force, responsive strategic planning is a necessity.

### 2.9.6 Concluding Remark

We have observed a number of distinguishing characteristics of the chemical sector. These are: (1) R&D activity; (2) Interdependence of chemicals; (3) Environmental issues; (4) Cartelization. It has been argued that each of these can, in its own way, affect the development of the chemical sector.

(1) Two major problems were seen to be associated with R&D activity: its degree of technological uncertainty and the issue of market development. Hence firms in the science-based industries attempt not only to reduce technological uncertainty, but also to bridge the planning gaps between innovation and product launch. This requires comprehensive strategic planning where a principal problem is the screening of alternatives. Screening in the chemical sector can be achieved economically and efficiently by employing the chemical laboratory as a "mini-pilot plant". The chemical laboratory is therefore a useful source of information that facilitates decision making with increasing confidence as the process of strategy formulation progresses.

(2) The property which characterizes chemicals is that a whole range of final products can be produced from relatively few raw materials in various combinations and proportions governed by scientific laws. Thus the most demanding applications of chemical R&D is in both inventing alternative production processes using different starting materials for producing an existing final product or even inventing a new final product. It has been concluded that the properties of chemical raw materials can affect industry development and problems of availability can be overcome if careful strategic planning triggers development of alternative processes for production of any chemical. This indicates that strategic planning in this sector could be beneficial.

(3) Another characteristic of the industry is the environmental problems associated with many of its products and production processes. Growing public awareness of the issue causes legislation that significantly affect development in the industry. Reliance on scientific knowledge is therefore required in careful strategic planning in order to change the polluting technology and replace it by a safe one.

(4) The fourth property which characterizes the chemical industry is its high degree of concentration. This has developed because of the high capital intensity of the industry. Its main effect on the industry should be a stabilizing effect - and since stability weakens the need for systematic strategy formulation - cartelization is a factor that acts to minimize the need for systematic strategic planning. Two contradictory views prevailing in the literature regarding the effect of cartelization on the rate of technological change have been outlined. This very contradiction suggests that market structure is not the dominant force affecting technological change. Rather, the present study proposes that research and development is the determining factor affecting technological change in science-based industries.

Since the chemical industry is based on scientific progress and R&D activity, cartelization cannot protect it effectively from rapid changes which once again demonstrates the need for comprehensive strategic planning in the chemical industry.

## 2.10 Summary and Conclusions

This chapter has briefly outlined the important models of the conventional corporate strategy literature. Two major inadequacies have been noted. One is the unsatisfactory treatment given "other than profit objectives". It has been concluded that this is particularly apparent when nationalized industries which are traditionally associated with non-economic objectives are considered. A second major shortcoming of conventional corporate strategy is the emphasis on financial strategies for the realization of growth objectives while ignoring the fact that science-based industries are necessarily associated with technological change. The chemical industry has been chosen as a well-established and recognized science-based industry and it is in this context that strategy formulation is discussed.

The on-going technological change in the chemical-based industries ipso facto implies that reliance on conventional financial strategy, that accepts technology as given, will not be adequate to realize the growth objectives of the chemical firm. A different approach relying on technological change is required, and this is pursued in Chapters 4, 5 and 6.

As regards the nationalized industries, it has been concluded that amongst other differences, these tend to be more socially committed and more specialized in a specific area than firms in the private sector. This implies greater commitment to non-profit objectives which may result in conflict with the profit objective. The problems associated with this are discussed in Chapter 3.

# CHAPTER 3

# CORPORATE OBJECTIVES

## 3.1 Introduction

Conventional corporate strategy models, notably those of Argenti[1] and Ansoff[2], are briefly concerned with the "representative private sector firm" where the assumption is that maximization of profit is the principal economic objective. Other objectives are subordinate to this and play a secondary constraining role. Hence in these models, reconciliation of objectives is not a major problem.

However, some authors, like Andrews,[3] although emphasizing the importance of social responsibility objectives, did not attend to the need for reconciling them with the economic objectives. On the other hand, commentators such as Sparkes[4] and Humble[5] do recognize that need and suggest ways of reconciling conflict between objectives. Sparkes, for instance, proposes "social budgets" alongside financial budgets. He argues that clear presentation of both of these will allow trade-offs between them. Conversely, it seems more reasonable to assume that bargaining power rather than "clear presentation" (it is questionable how clear social accounts can be when even financial quantitative ones are easily manipulated) will determine the priorities and final compromise. Solutions like this leave the problem of reconciliation of objectives in an unsatisfactory situation.

Therefore, an attempt will be made in this chapter to outline a relatively simple framework that uses historical, external, intentional and innovative standards in setting multiple objectives at a target and at a constraint level. The difference between the two levels determines a margin within which conflicting objectives can be reconciled and a consensus level can thereby be reached.

The existence of a gap between the innovative and other standards indicates that growth can mainly come through technological change. This is particularly important for a specialized producer operating in a science based industry that is declining or growing slowly, and who cannot diversify because he is either too specialized and enjoys some competitive advantage or constrained to a particular field by non-economic objectives. The chapter suggests that this can be best demonstrated by reference to such a real-world producer.

However, before the above framework is presented, the chapter discusses two different approaches to the issue of reconciling objectives. Both schools express dissatisfaction with the single objective of profit maximization, but one mainly challenges the 'maximization' notion, while the other questions the exclusive attention to profit and suggests that it is possible to have more than one component (such as profit) in the objective function.

The first approach is presented by Cyert and March[6] who have proposed a behavioural model of the firm. The second approach is Williamson's[7] managerial discretion model.

## 3.2 The Cyert and March Organisational Goals Model

As Cyert and March have noted, the conventional theory of the firm which concentrates on 'profit maximisation', was designed to explain at a general level the way resources are allocated by a price system. They argue that for the problem of internal allocation of resources, the 'maximisation' notion is non-operational and an alternative analytical framework is required. The Cyert and March behavioural approach is chiefly concerned with constructing a model responsive to this requirement.

Their organisational goals model is based on the premise that firms and in fact most organisations, are purposeful coalitions (it should be noted that their concept of coalition resembles the notion of 'stakeholders' mentioned in previous sections).

### 3.2.1 Formulation of Objectives

Three processes in which the objectives of the coalition are determined are suggested: [8]

1. A bargaining process by which general terms of the coalition formation are negotiated.
2. An internal control process having a stabilising effect on objectives.
3. A process of modifying coalition agreements according to new circumstances.

Coalition building through bargaining

A basic problem in the process of coalition formation is the distribution of benefits among participants. Claims of some potential coalition members may be inconsistent with other demands. However because of partial ignorance and bounded rationality, coalition members do not anticipate effectively all possible future situations and the bargaining process results in incomplete side-payments (or benefits) agreements.

During formulation of these agreements, many of the organisational objectives emerge. It appears that the incompleteness of the side-payments agreements tends to result in the following attributes in the emerging objectives: [9]

(i) They are imperfectly rationalised, because the test for consistency is normally far from complete.

(ii) Some objectives are stated in the form of aspiration level constraints; e.g., "We must allocate 10% of our total budget to research".

(iii) Some objectives are stated in a non-operational form. This is partly explained by Cyert and March by the fact that non-operational objectives such as progress, benefit, and so on, are consistent with virtually any set of objectives.

Thus the main feature of the bargaining process, if it is to result in a viable coalition is the avoidance of full specification in determination of objectives. This feature explains the existence of inconsistency among objectives which is a conspicuous characteristic of organisations, not accounted for by the classic economic solution to the problem of organisational goals. The latter attempts to define a joint preference ordering for the coalition, which pre-supposes an organisation that consists of individuals having identical tastes. However, it should be emphasized that the activity of most organisations usually involves association of many specialists who necessarily have different experiences and consequently different preferences. Therefore the classic assumption that such individuals may be grouped under joint preference function seems unrealistic.

Stabilisation of objectives

The constraints on the bargaining process (partial ignorance and bounded rationality) explains the incompleteness of side-payments agreements and the main attributes of the resultant objectives, but are inadequate for explaining the latter's apparent stability.

Cyert and March argue that stability of objectives in organisations is mainly achieved by both mutual control systems and formal or informal organisational precedents. The two control systems, the budget and allocation of functions are seen to stabilise expectations by defining limits of discretion. This would not only confine the individual(s) to act within the agreed limits, but also constrain other coalition members from prohibiting action within those limits. These restrictions should assist in drawing attention to and concentrating efforts on operational matters. Use of precedents in order to remove from conscious consideration other possible situations serves the same purpose.

Changes in objectives

Although considerable stability is achieved by avoidance of formulating fully specified agreements and use of mutual control systems and organisational precedents, Cyert and March do concede that the demands made on the coalition by its members do change with time, even if the composition of the organisational coalition remains constant. Two kinds of changes are possible:

(i) Changes in the quantitative level of demands or level of aspirations. These variations are related either to changes in achievement of the participant himself and/or achievement of others in his reference group. However Cyert and March admit that not much is known about the parameters of the relation between achievement and aspiration.

(ii) Changes in the nature of the demands, i.e., new objectives may be sought. This is because each individual has a long list of demands which cannot be tackled simultaneously, hence attention is focused only on a small subset of the total set of demands. Experience may generate problems which shift this focus of attention to another subset of demands, thus resulting in an apparent change in the nature of member's demands. Thus problems may appear to evoke goals.

### 3.2.2. Variables Affecting Formulation of Objectives

From the three processes (the bargaining process, internal control process and adjustment process) by which Cyert and March argue that organisational goals are formed, it can be seen that Cyert and March identify two sets of variables affecting the goals of an organisation:

(i) variables affecting the choice of goals:

a. composition of the coalition - if new members are entering and old ones are leaving, the set of goals is likely to change.

b. allocation of functions - because goals for a specific decision are the goals of the subunit making that decision.

c. definition of problems facing the firm - it was argued that goals are evoked by problems.

(ii) variables affecting the aspiration level on any specific objective: Cyert and March suggest that the aspiration level is some weighted function of three variables: the organisation's past goals, the organisation's past performance, and the past performance of other "comparable" organisations.

As far as (i) is concerned, it appears that the three variables proposed by Cyert and March do affect the choice of a particular set of goals, but another important variable, which they ignore, current societal trends may add goals (e.g., social responsibility) to the chosen set or even favour moves such as government intervention that may also add goals (e.g., national objectives).

Turning to (ii), it is not clear how the three variables are weighed by Cyert and March. Nevertheless, their three variables are preoccupied with the past; surely level of aspiration is not only a function of past 'facts' as Cyert and March argue, but also of future expectations, which may refer to the past but need not continue it. In fact, expectations and hopes which affect aspirations are likely to represent in many cases sharp or moderate departures from the past.

### 3.2.3 Resolution of Conflict

While formulating their framework for setting organisational goals, Cyert and March recognise the possibility of conflicting objectives and introduce the concept of quasi-resolution of conflict as their solution. They argue that most organisations most of the time exist and prosper with considerable latent conflict of goals; and this is attributed to several organisational phenomena and modes of behaviour. These are briefly discussed below.

Organisational slack

Organisational slack is defined as the difference between total resources and total necessary payments. Classic economic theory regards slack as a result of market imperfections, but Cyert and March see organisational slack as a result of imperfect information. Some typical examples of slack include: payments of dividends to stockholders in excess of the minimum necessary to keep shareholders within the organisation; wages in excess of those required to maintain labour are paid, etc. Cyert and March[10] suggest that slack may be generated if a system of satisficing decision rules is employed by the firm. Such a system will tend to underexploit the environment and leave excess resources that may be seen as slack which acts as the insulating layer that protects the firm from environmental changes. Thus if the environment becomes less favourable, slack represents a cushion which permits firms to survive in the face of adversity.

Resource scarcity results in renewed bargaining and tends to cut heavily into the excess payments distributed during affluent times. But, as Loasby[11] has pointed out, it should be noted that the firm may be protected from changes in the facts but much more vulnerable to changes in expectations. Thus if the environment sets a new level of expectations, the old set of demands may overnight become unacceptable and slack (defined as excess of resources over demands) loses its meaning and insulating power.

The use of non-operational goals

Another organisational characteristic which contributes toward quasi-resolution of conflict is the use of non-operational goals. These tend to be formulated in wide and general terms and are not rigourously defined. As such. they are often consistent with virtually any set of objectives. In commenting on this matter of non-operational goals, Loasby[12] suggests that "When critical problems must be faced and tackled, meaningful objectives are essential, but in situations where conflict would be damaging but its resolution is not important, a little well-designed obscurity can be very helpful." However care should be taken in exercising this means, since resolution may become important as time passes (or when the agreement is to be implemented) and the latent conflict obscured by noble phrases will need more effective and permanent means of reconciliation.

Local rationality

Local rationality derives its significance from allocation of functions, which was mentioned previously as a component of the process of stabilisation of objectives (see p. 40). Allocation of functions is a device for avoiding conflict by giving some measure of autonomy to coalition members thus keeping the incompatibles apart. This assumes that when locally produced solutions are combined they are likely to result in an overall rational solution. However as Loasby has argued, locally reasonable decisions may prove disastrous to the organisation as a whole. But it appears that there is value in this notion of local rationality as it enables the organisation to reduce a situation involving a complex set of inter-related problems and conflicting goals into a number of simplified problems.

Sequential attention to goals

Sequential attention to goals is related to local rationality. Both are characterised by their tendency to break down a complex problem into its components which represent simpler solvable problems. The difference is that local rationality tends to distribute the sub-problems over space, and sequential attention to goals distributes them over time. Therefore as Loasby[13] has indicated, sequential attention to goals may be used either between departments, to assure that at some point in time it is a centre of interest, or within a department to resolve conflict by avoiding the need to make explicit the exchange rate between departmental sub-objectives. However, the resemblance of this means to that of local rationality suggests as Loasby[14] has argued, that both are open to similar criticisms.

### 3.2.4 Interim Conclusion

The analytical framework that was developed by Cyert and March for explaining the stability of the coalition, provides the basis for the assumptions which underly their choice of a particular set of goals that respond to operating problems. Although Cyert and March[15] admit that conflict is never fully resolved, the justification of their model is that it permits the business firm to make decisions with conflicting goals under many conditions.

It should be noted that Cyert and March are dealing with the operating level of objectives which are necessarily associated with operating decisions. Loasby[16] classifies operating decisions according to three characteristics:

(i) their effects are localised so that decisions may be made within a narrowly-defined system;

(ii) they involve a limited number of variables;

(iii) similar decisions need to be taken quite frequently; thus they may lend themselves to be standardised and programmed.

These characteristics permit operating decisions to deal efficiently with most organisational problems. But on the other hand, they confine operating decisions within a narrowly-defined space of solutions, thus excluding potentially promising opportunities or potentially disruptive threats. Therefore Cyert and March's firm which employs objectives and decisions at the operating level tends to avoid long-term problems and to concentrate on day-to-day matters that are characterised by being limited in scope and occuring frequently.

It appears that such a system may have some survival value and may be useful for organisations which are survival-oriented. However, the features just discussed make it unable to identify the need for strategic change, and therefore render it inadequate for a firm which is growth and development oriented, particularly if, as shall be seen later, the firm operates under conditions of imperfect competition.

An attempt to use Cyert and March's system of operating objectives for identifying a need for strategic change was made by Sutton[17]. In developing a behavioural model for diversification, Sutton discusses the need for a trigger for initiating an active search for new opportunities that may represent strategic change. Referring to the model proposed by Cyert and March, Sutton simply suggests that a failure to achieve accepted goals would prompt re-appraisal of existing strategy which may in turn lead to consideration of strategic change. In more specific terms, it is proposed that re-appraisal occurs whenever profitability falls below a standard level of satisfactory performance. This standard is determined by the performance of comparable firms serving as accepted reference firms. Sutton argues that specialized and non-specialized firms will differ with regard to reappraisal of current activities and their incentives to diversity. Thus for a relatively small group of specialised firms facing a fall in profitability, reappraisal would be discouraged because, due to its special assets, such a group would normally tend to take standards from each other. The resulting general decline in standards will be a disincentive to consider reappraisal. Reappraisal is more likely to occur when a non-specialised firm drawing its standards from a large number of reference firms experiences a decline in profitability, as now the fall in the firm's profits will show relative to a wider group.

Sutton's argument above depends on a particular choice of external reference standards - similar firms in the same industry. Reliance on other standards, e.g., historical standards of each firm would reveal no reason for difference, in consideration of the need to diversify, between specialised and non-specialised firms. Clearly, the use of the Cyert and March model as proposed by Sutton does not explain that difference. Other reasons, such as the practical difficulties associated with the change in specialised activities, should account for the observed difference in behaviour between specialised and non-specialised firms.

Nevertheless, the most valuable contribution of Cyert and March is not the set of economic operating objectives (profit, sales volume, market share, stock levels and volume and stability of production) which they propose, but in the framework they suggest for resolving the inevitable conflict between objectives. Although the concepts formerly discussed (e.g., organisational slack, sequential attention to goals, etc.) which are used to explain how conflict is resolved, were developed for operating objectives, they may be applicable also to the strategic level of objectives. At this level attention should be given primarily to the potential conflict between economic goals and social responsibility.

But before doing this, let us turn to Williamson's model which disputes the efficacy of restricting the motivation for management behaviour in the business firm exclusively to profit.

## 3.3 Williamson's Managerial Discretion Model

Williamson's model rests on two basic assumptions:

(i) The complex objectives of managerial behaviour can be approximated by an objective function which includes a limited number of variables.

(ii) Managers will seek to optimise the value of this function.

It should be noted that whereas (i) disputes the exclusive attention to the profit objective, (ii) is in general agreement with the maximisation notion which underlies the classic concept of profit maximisation.

The relatively long list of possible personal objectives of managers is compressed by Williamson to include staff, emoluments and discretionary profit.

Staff for Williamson means expenditures on staff, increases of which normally tend to increase personnel controlled by the manager and favourably affect his salary and status. Emoluments represent management slack in the sense used by Cyert and March (see p. 43). This is because emoluments represent excess benefits that even if removed would not cause the managers to leave the coalition. However, these benefits serve as some indirect source of status and prestige, hence they are desirable as a means for satisfying goals in each of these respects.

Williamson's use of the terms staff and emoluments stems from his attempts to translate managerial motives such as status and prestige into measurable terms. The notion of "expense preference" is introduced in order to facilitate this translation.

By expense preference it is simply meant that some types of costs have positive values attached to them. This is a departure from conventional economic analysis which treats all costs symmetrically, assuming that individuals are indifferent toward costs of all types. Expense preference treats costs asymmetrically as some costs are preferred to others.[18] Thus, for example, it is assumed that management has a positive expense preference for both staff expenditure and emoluments or management slack in the form of various costs such as expense accounts, executive services, office suites, etc.

In addition to staff and managerial slack, Williamson introduces discretionary profit as the third component of the management objective function. Discretionary profit is defined as the difference between actual profit and a minimum performance constraint. It is suggested that the larger this difference is the more discretion managers would experience in extending staff and allocating funds for emoluments.

Management is seen by Williamson as the principal member of the coalition, this position of primacy is granted because of management's role as chief coordinator and initiator as well as having preferred access to information. Although this picture appears fairly realistic, it should be noted that these characteristics vary at different levels of management and also their distribution among members of the coalition depends on the nature of the organisation. In organisations which include in their board of directors, in addition to executives, workers and/or public representatives, the latter have fair chances to become initiators and are likely to have at least similar access to information. However, the major task of management as principal coordinator does justify specific attention to this group of the coalition.

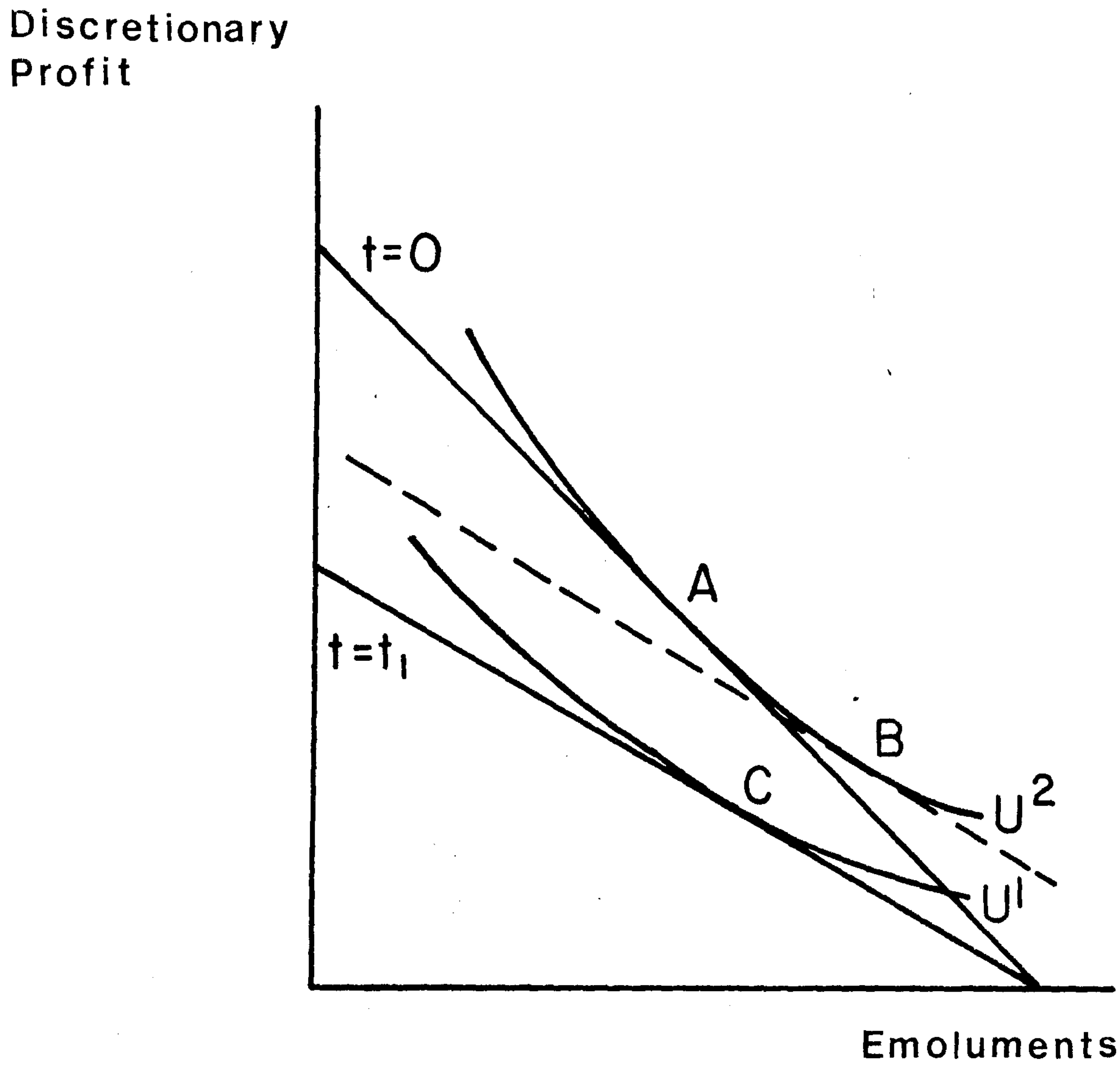
### 3.3.1 General Properties of the Managerial Discretion Models

Williamson's assumptions outlined in the previous section require that the firm's objective function be extended to comprise two cost terms, emoluments and staff, in addition to the profit component.

Emoluments are seen as economic expenses which are associated with zero productivities, hence, any increase in emoluments will cause a reduction in discretionary profits. Therefore discretionary profits are directly related to emoluments. Williamson conveniently describes this relationship as a linear function having a negative slope as t = 0 and t = 1 in Figure 3.

In contrast, increases in staff may be associated with some kind of productivity (e.g., expansion of sales) and consequent rise in discretionary profit. However, at some level of staff, the phenomenon of diminishing returns is felt and discretionary profit may decline with each increase in staff until a point is reached where discretionary profit is eliminated. This relationship may be appropriately represented by a concave function having one maximum (see Figure 4). In many firms, staff appears to have a more explicit impact on the cost structure than emoluments, and considering the variety of ways in which staff contributes to managerial satisfactions, it may be expected that management will exhibit a more positive preference toward staff. Thus a model introducing staff into the objective function appears to have the most important im-

Figure 3: The effects of constant tax rates on emoluments




Source: O.E. Williamson p. 52

plications and therefore has been chosen to be discussed here in some detail. As far as the emolument model is concerned, it should be noted that the argument presented in it exactly parallels the one given in the discussion of the staff model. Hence conclusions relevant to the staff model are valid for the emolument model as well and the discussion of it can be omitted here.

### 3.3.2 The Staff Model

The following terms are important for the analysis:

$X$ = output

$P$ = price

$R$ = revenue = $PX$

$C$ = production costs

$E$ = environmental conditions (a demand shift parameter)

$S$ = expenditure on staff, usually reflects the number of employed staff and/or general selling expenses

$\Pi$ = actual profit (before tax) = $R - C - S$

$\Pi_o$ = minimum (after tax) profit required

$t$ = tax rate

$(1 - t)\,\Pi - \Pi_o$ = discretionary profit

Williamson suggests that for every value of staff there exists an optimal value of output denoted as $\hat{X}$, thus $\hat{X}$ may be considered to be a function of $S$ that is $\hat{X} = f(S)$.

If environmental conditions $E$ are given, profit depends on the combination of $X$ and $S$. This can be expressed as:

$$\Pi = g(\hat{X}, S) \text{ where } E = \text{constant}$$

Substituting for $X$, one gets $\Pi = g\{f(s), S\}$ this term can be more simply written as $\Pi = g'(S)$.

Thus under given environmental conditions profit can be plotted as a function of staff. As was argued previously, increases in staff would tend to increase profits until a point (or more accurately a region) of diminishing returns is reached where additional staff results in a reduction in discretionary profits.

Effect of positive preference toward staff

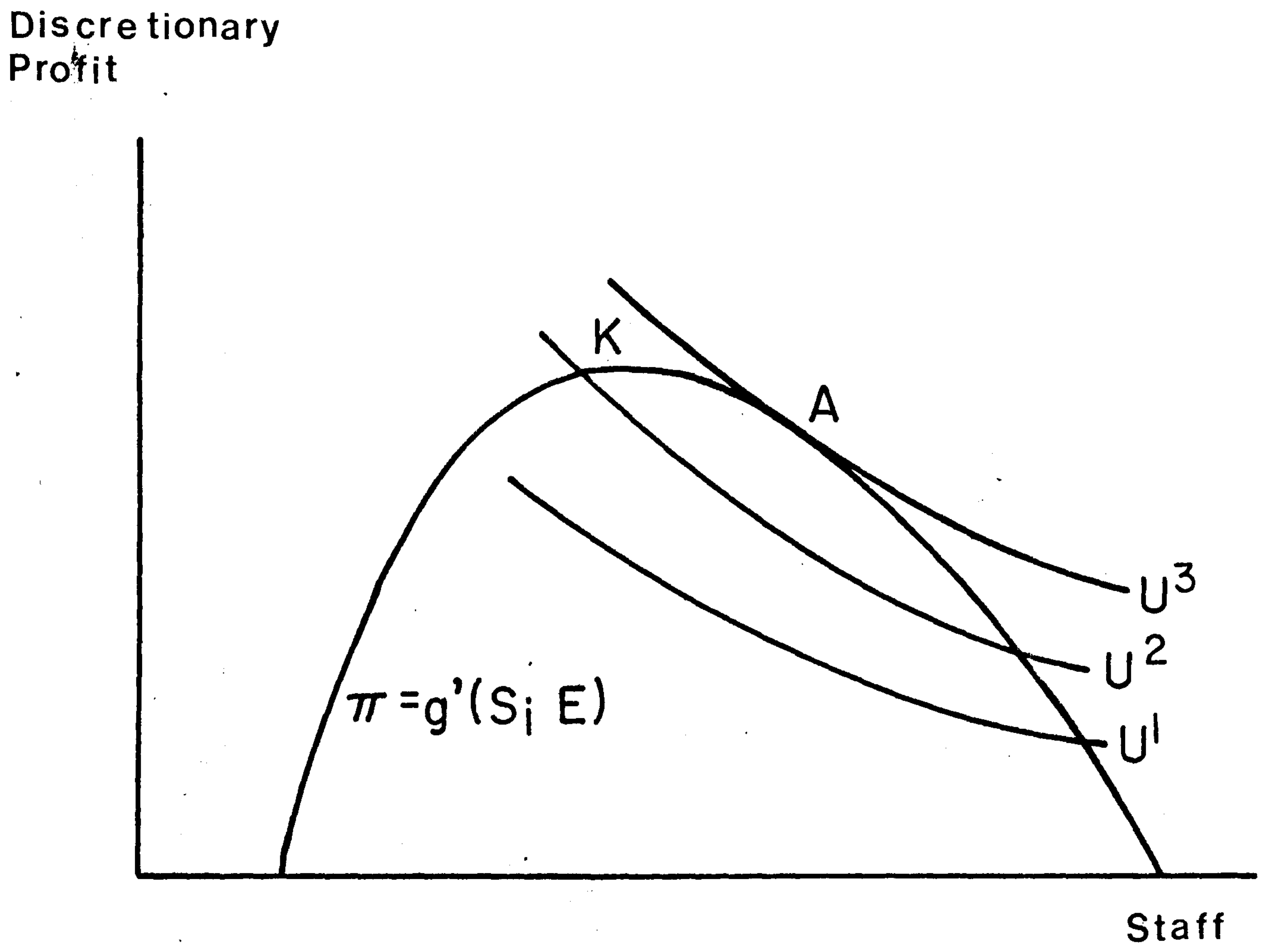
As can be seen in Figure 4, increases in staff would tend to increase profit until a point of diminishing returns to staff is reached, K on graph. The indifference curves $U^1$, $U^2$ and $U^3$ represent a positive preference of management toward staff. Equilibrium would be reached at the tangency point - A - of $U^3$ and the profit curve, which represents maximum utility for management.

Thus for any given profit curve, equilibrium will be determined by specifying the slope of the indifference curves. When this slope is zero, equilibrium will be reached where the corresponding indifference curves will tangent the profit curve at point K, which represents the maximum utility for a manager for whom the marginal utility of staff is zero - a profit maximiser.

Williamson therefore treats profit maximisation as a special case. His analysis is based on the assumption that because of the varieties of ways in which staff could contribute to managerial satisfaction, it is unlikely that the zero marginal utility condition will be realised.

From observing Figure 4, one may also conclude that if the profit curve would have been sharply peaked, discretionary profits would become sensitive to changes in staff and the equilibrium point (even for a firm with a positive preference toward staff) would approach the profit maximisation position. But if the profit curve becomes relatively flat, equilibrium position for a manager with a positive preference toward staff would be further removed from a profit maximiser's equilibrium position.

Figure 4: The effect of positive preference toward staff




Source: O.E. Williamson p. 43

Effect of taxation on staff

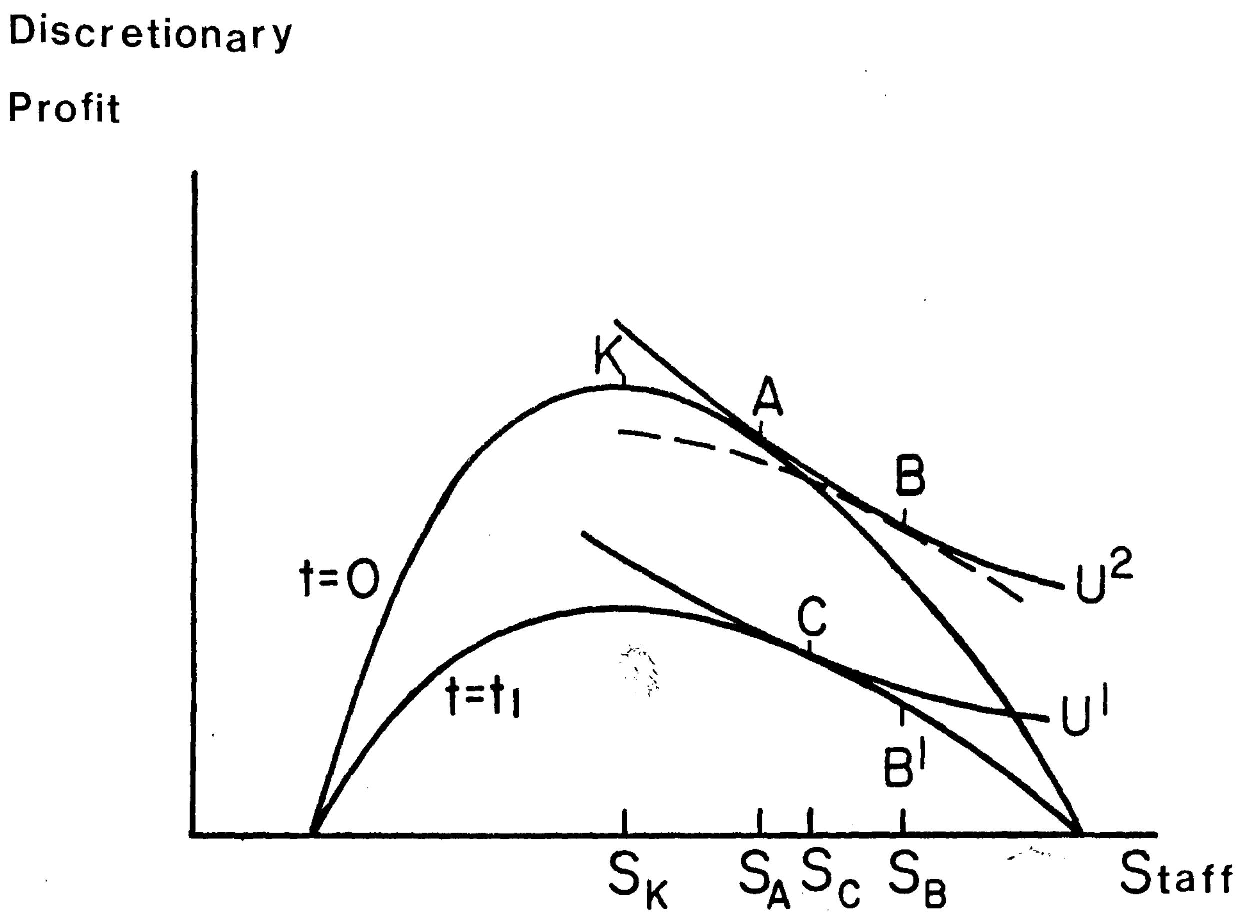
Displacement of equilibrium is achieved by employing three taxation regimes: (I) tax rates; (II) application of a progressive tax rate; (III) levying a lump sum of tax.

The effects of the first regime are shown in Figure 5. Discretionary profit for Figure 3 was defined as $\Pi - \Pi_o$ where $\Pi$ was actual profit and $\Pi_o$ the minimal after tax profit requirement. If a tax rate t is introduced, discretionary profit becomes $(1 - t)\ \Pi - \Pi_o$ which similarly to the construction described for Figure 4 is seen as a function of staff. Thus where there is no tax, i.e., $t = 0$, the term for discretionary profit reduces to $\Pi - \Pi_o$ and the profit curve is identical to the one described in Figure 4. However a tax rate $1 > t > 0$ would result in a profit curve that for each value of S would yield lower profits than the corresponding ones for the zero tax case. At tax rate $t = 0$, the optimum position is again obtained at A, the tangency point between $U^2$ and the profit curve. At a higher tax rate, such as $t = t_1$, a lower indifference curve $U^1$ will have a tangency point with the resulting profit curve establishing a new optimum position at C. As drawn, the optimal choice of staff increases ($Sc > S_A$).

Since staff and profits are substitutes, the firm's response to increase in the tax rate can be seen as comprising two contributions, i.e., income and substitution effects.

The decomposition of the firm's after tax optimal choice is shown by introducing a compensated tax change. This compensation is in the form of a lump sum grant simultaneously awarded with the increase in the tax rate and as shown in Figure 5, just large enough to enable the firm to continue to realise the utility represented by indifference curve $U^2$. The resulting profit curve is the dashed curve seen as a vertical displacement of the curve $t = t_1$. Since $1 > t_1 > 0$, the slope of the curve $t_1$ is

Figure 5: Effect of taxation on staff




Source: O.E. Williamson p. 46

everywhere less than the corresponding slope of the curve $t = 0$, the curve $t = t_1$ appears flatter and, as argued above, tangency between the dashed curve and the indifference curve $U^2$ will move to the right of A and establish a new equilibrium position at B. This shift from A to B is the contribution of the substitution effect which is shown to be positive. Staff becomes relatively more highly valued because the 'price' of taking satisfaction in the form of profit increases. Therefore the response to compensated tax always appears as an increase in staff due to a substitution of staff for profit thus $S_B > S_A$. In moving from curve $t = 0$ to a lower profit curve such as $t = t_1$ , three types of downward displacement of the indifference curves are conceivable:

(i) a displacement that does not involve a change in slope

(ii) a displacement accompanied by an increase in slope

(iii) a displacement followed by a decline in slope.

As Williamson argues, (i) does not seem realistic. It represents a condition where, given the level of staff, the extent of the positive preference toward staff remains unchanged even in face of falling profits. (ii) implies that the level of positive preference toward staff will rise as profits decline. Williamson suggests that (iii) is the more realistic case since normally the preference toward staff remains positive, although its magnitude tends to decline if profits decrease, hence attention is restricted to (iii). This restriction is justified if like Williamson, one assumes that staff is not an inferior good (product).

Thus the slope of $U^1$ is smaller than that of $U^2$ and tangency occurs not at $B^1$ but at C. The shift from B to C represents the income effect; that is, the rising 'price' of taking satisfaction in the form of profit decreases the firm's available "income" and it has to reduce its "consumption" of staff accordingly. In this case, therefore, the income effect will be negative and $Sc < S_B$.

The overall contribution toward increase of staff will be a combination of the income and substitution effects and hence will depend on their relative magnitudes. As drawn in Figure 5, this contribution $Sc - S_A > 0$ will normally be positive. Although when the firm is pressed to satisfy its minimum profit constraints (which means that there is hardly any discretionary profit), this contribution is likely to become negligible or even negative.

The effects of progressive tax rates

The effects of progressive tax rates are studied with reference to constant tax rate $t_1$, as shown in Figure 6. In such a regime, the tax paid, T, is a function of actual profit, $\Pi$, therefore T: $T = h(\Pi)$.

Then it may be written that:

$$\text{discretionary profit} = \Pi - h(\Pi) - \Pi \quad ,$$

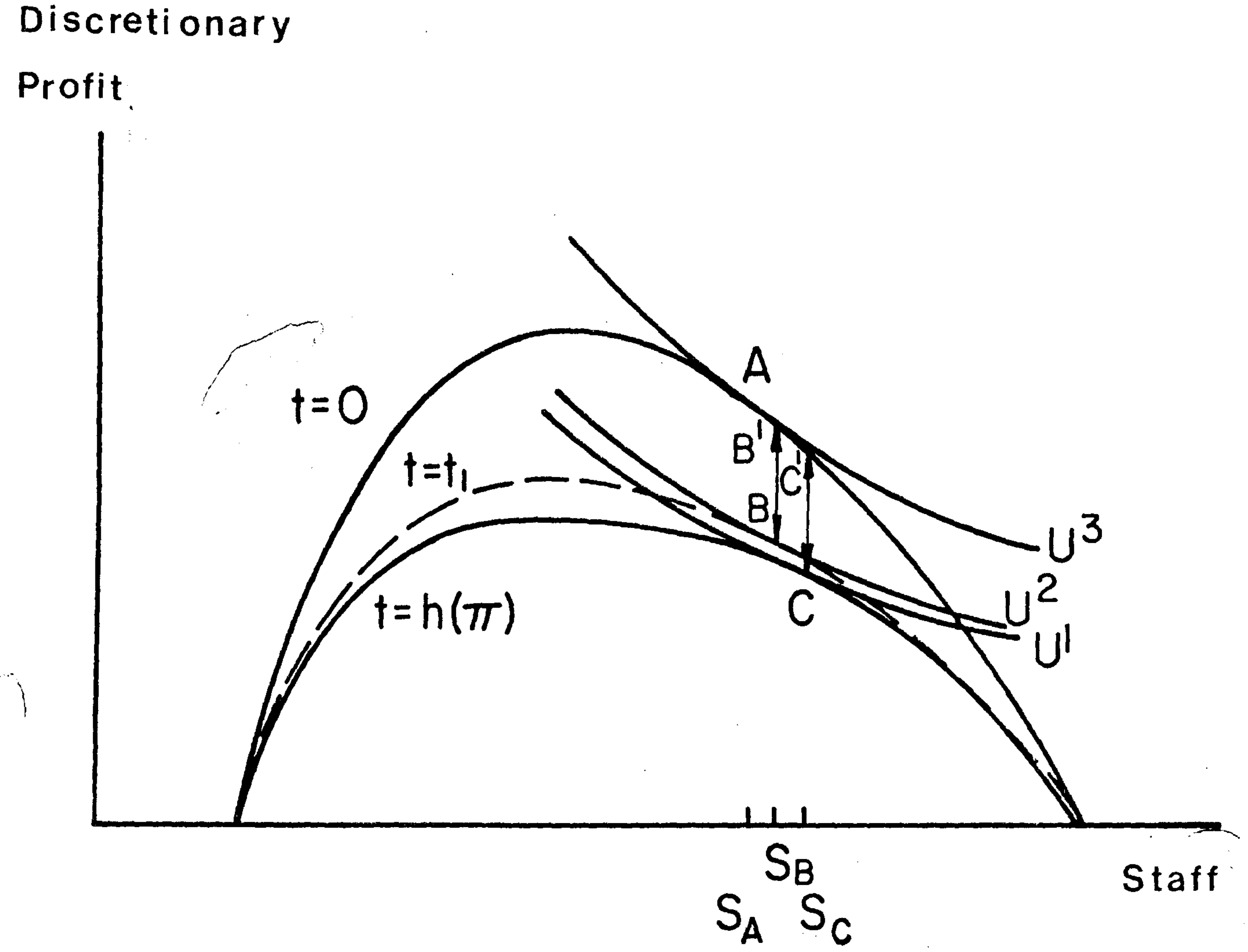
and since $\Pi = g'(S)$, this can be expressed as a function of staff. By definition, under a progressive tax scheme, the amount of tax collected is directly related to the level of profit. The higher this level is, the more tax is collected, therefore as shown in Figure 6 the solid curve, $t = h(\Pi)$, representing profit under the progressive tax system is flatter than the dashed curve $t = t_1$ representing profit in a constant tax system.

Excluding again the possibility that staff is an inferior good, tangency with indifference curves is shifted from A to C yielding $Sc > S_A$.

C' in the diagram represents discretionary profit before tax corresponding to staff Sc. C represents the respective discretionary profit after the progressive tax was collected. The amount of tax is given by CC'.

Williamson requires that a profit curve under constant tax is chosen so that tangency between the resulting dashed profit curve and the indifference curves occurs at a point that yields precisely the same

Figure 6: The effects of progressive tax on level of staff




Source: O.E. Williamson p. 48

amount of tax as was collected under the progressive tax regime.

Due to this requirement the marginal tax rate under the constant profits tax is less than it would be under the progressive tax scheme. Therefore under constant tax rate there is less incentive for the firm to absorb profits and take its satisfactions through staff. Thus $S_B < Sc$.

The effects of the third taxation system, a lump sum tax, can be investigated in a similar manner. Increases in the lump sum tax would push the profit curve, t = 0, vertically downward. Again, excluding the inferior good possibility for staff would tend to reduce the indifference curve's slope and result in tangency at a lower level of staff than under an inferior good assumption.

### 3.3.3 Interim Conclusion

The different response that the model exhibits for each tax regime is a direct consequence of the combination of two factors:

(i) Williamson's assumptions that:

(a) the slope (more accurately its absolute value) of the indifference curve is greater than zero and less than one, i.e., managers possess a positive preference toward staff.

(b) a move from a certain profit curve to a lower one is associated with a reduction in the positive preference toward staff, which is mathematically displayed as a fall in the slope of the corresponding indifference curve. Accepting this behaviour excludes the possibility of staff being an inferior good.

(ii) Each tax scheme differently affects the resulting discretionary profit curve.

The first factor includes the two assumptions which are fundamental to Williamson's model.

The first assumption extends the narrow scope of the profit maximisation model (which treats only profit as a legitimate commodity, thus implying that the slope of an indifference curve between profit and a cost item such as staff will be always zero) to comprise other legitimate commodities by allowing the slope of the indifference curve to move between zero and one. It should be noted however, that this legitimation may become a controversial issue. Loasby,[19] for instance, has argued that by ruling that costs are legitimate commodities, Williamson is at variance with two other formulations. The first one is wage theory whose underlying contention in contrast to Williamson is that costs must not become a subject of preference. The second is the precept that X - inefficiency - should be eliminated. By X - inefficiency - Leibenstein[20] meant misallocation of resources beyond the one attributable to market imperfections. Williamson does not seek to eliminate such unnecessary costs (or X - inefficiency) but regards them as a direct source of satisfaction to management. This apparent contradiction probably stems from the different starting points of the two views. Williamson employs in his model a positive approach, whereas both wage theory and Liebenstein's proposition are associated with a normative attitude.

In his second assumption, Williamson narrows the range of possibilities and excludes the case of costs that may be regarded as inferior goods. Thus the slope of the indifference curves declines as the profit curve falls. The second factor affecting the different response of the firm under different tax regimes is the latter's varying effect on the profit curve. Each tax scheme produces a different profit curve obtaining a point of tangency with the utility curves, reflecting the combined income and substitution effects.

Williamson's model may therefore serve as a useful instrument for indicating directions of change. Magnitudes can be predicted only after managerial utility curves are fully specified. Williamson's partial specification of managerial indifference curves is not accidental; it should be noted that for a profit maximiser the indifference curve is specified and direction as well as magnitudes of change can be determined. But this very specification of zero marginal rate of substitution was challenged by Williamson and claimed to be unrealistic.

### 3.4 Concluding Remark

As has already been said, conventional corporate strategy models avoid the problem of reconciliation of objectives by concentration on a single objective.

On the other hand, we have seen that the behavioural approach (put forward by Cyert and March) and the managerial discretion approach (outlined by Williamson) tackle the conflict between objectives in a different way.

Thus, Cyert and March[21] discuss stabilisation of the coalition in terms of resolution of the conflict between objectives of the coalition members. They are interested in the behavioural process of reaching a consensus and not in the achieved equilibrium of the objective function. The latter is the focus of Williamson's model.[22]

Williamson suggests trade-off between the conflicting objectives and argues that the functional relationship between objectives and the shape of the managerial indifference curves, determine the nature of the trade-off and the achieved equilibrium of the objective function.

The present study suggests that the behavioural approach is valuable in emphasising the need to resolve conflict and preserve the coalition, whereas the managerial discretion approach can be useful for indicating directions of change in the level of aspirations of the coalition members. The two approaches are therefore complementary and lend themselves to synthesis. To this we turn in the following section.

## 3.5 A Simplified Framework for Reconciliation of Conflicting Objectives

### 3.5.1 Introduction

Section 3.1 has pointed out that conventional corporate strategy models treat inadequately reconciliation of objectives. This inadequacy has led to the consideration of the behavioural and managerial discretion approaches in sections 3.2 and 3.3.

The concepts developed in those approaches will be used in this section in formulating a relatively simple framework for reconciling objectives. Essentially the framework suggests resolving trade-offs by setting objectives at a constraint level and a target level. In formulating the constraint-target approach, the concept of reference standards is introduced and their role in determining the two levels is discussed.

### 3.5.2 Resolution of Trade-Offs

The way proposed here and graphically represented in Figure 5 for resolving trade-offs is simply to set objectives at two levels:

(i) a constraint level which is the minimum requirement for preserving the coalition.

(ii) a target level at which each one of the various coalition members is aiming.

It is suggested that the difference between the two levels defines a margin within which trade-offs are feasible and conflicting claims can be satisfied. This satisfaction involves a bargaining process, along

Figure 7: Setting an objective in the target-constraint approach

target level ---------------------------------------- A

Consensus level ________________________________________ C

Constraint level ---------------------------------------- B

Note that:

1. Both the target and the constraint levels are set by the application of reference standards. The former is affected by innovative and intentional standards and the latter by historical and external standards.

2. The difference A-B defines a margin within which the interplay of forces - the effect of other objectives and bargaining power of proponents and opponents - determines the consensus level C.

similar lines to the one proposed by Cyert and March, which results in a consensus level (see Figure 7).

### 3.5.3 Reference Standards

In the real world, knowledge is imperfect and it is difficult in conditions of partial ignorance to arrive at the theoretical minimum or maximum of the complex objective function. Therefore it is suggested to use suitable reference standards that may represent minimal or maximal claims of coalition members.

In discussing the process of problem finding, Loasby [23], following Pounds and Suckling, suggests four categories of reference standards:

(i) historical - the record of past situations

(ii) external - the apparent situation elsewhere

(iii) planning - the anticipated situation

(iv) imaginative - some notion of what does not exist but might be created.

These standards appear appropriate also for our purpose of setting objectives at two levels of desirability (a target and a constraint level). It is proposed that the first two categories of historical and external standards may be used in determining the lower limit or the constraint level of an objective. Of the last two categories, planning standards appear to pose some methodical difficulty. Planning standards are to be derived from plans, but normally plans are based on objectives. Thus it is difficult to see how planning standards perceived in this way can be used for establishing a desired level of objectives. To get around this difficulty, it is proposed to replace planning by intentional standards which together with imaginative standards may be employed, as discussed later, in setting target levels of an objective.

### 3.5.4 Determination of the Constraint Level

#### 3.5.4.1 Historical and External Standards

The implicit assumption behind the use of historical standards for extrapolation is that the past can serve as a good guide to predict the future. Loasby argues that for this purpose the value of a historical standard depends on both its content and continued relevance. Three factors may determine content. The first is the range and weighting of the experience built into the standard, i.e., the size of the sample and also its biases. The second is the accuracy with which that experience is perceived, that is closely associated with the data-collection system. The third is the interpretation of experience which has to do with the quality of the analysis applied to the sample results. Loasby asserts that confidence in the use of historical standards as a tool for problem recognition is directly related to the three factors just mentioned and particularly to the size of the sample. Thus if the sample is small, the confidence in the results will be fairly low regardless of the effectiveness of the data collecting and processing systems. Since, as Pounds has argued, managers tend to employ small samples for historical standards, care should be taken in using them as a guide to the future.

Application of historical standards

In this work, however, historical standards are merely intended as a minimal requirement in obtaining a particular objective and not as an ideal guide for a future level of performance. In other words, this type of use represents a very limited application of historical standards to future situations. The implicit assumption here is that participants in a bargaining process will usually require better terms or at least equal, but certainly not worse terms than they had been able to obtain in the past. This attitude, which is not rare in political debates, trade union negotiations, board meetings or other bargaining situations, appears to be consistent with normal behaviour. On this basis, the use of historical standards as a lower limit for obtaining a particular objective seems to be reasonably justified.

Possible bias of historical standards

In this context, the point Loasby has made about the continued relevance of historical standards to future circumstances is also relevant to their use as a minimal requirement imposed on an objective. Thus if essential elements in a new situation differ significantly from those in the old one, historical standards may either set a too low level of requirement in a favourable environment, or a too high level when the new setting is appreciably worse than the old one (see Figure 8). The first kind of error is unlikely to endanger the survival of the coalition for at least two reasons:

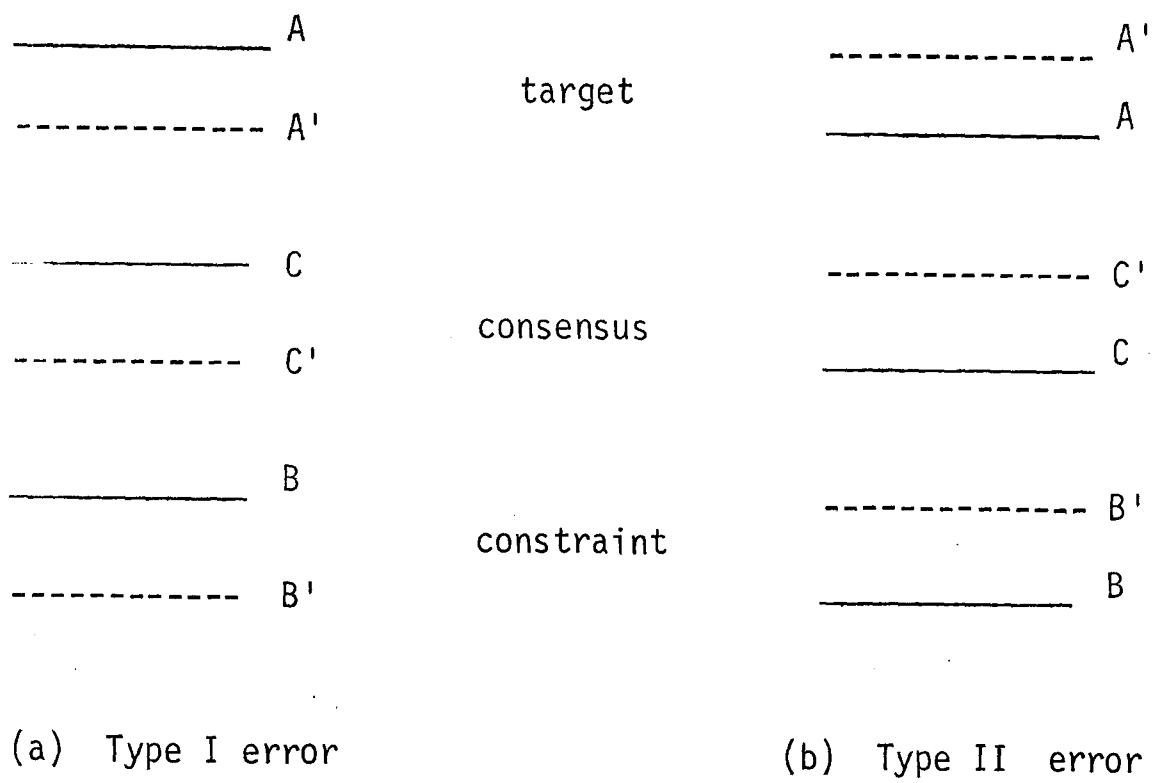
(i) This type of error is likely to occur when the new situation is better than the old one. It is not expected therefore that the lower limit would be realised.

(ii) It implies a lower than required constraint level. Such a low requirement may even provide a further cushion (B-B') in face of unexpected difficulties (see Figure 8a).

The main effect, however, of an error of the first type would be to reduce the requirements on the performance of the consensus level.

But the error of the second type, i.e., insistence of coalition members in new and worse circumstances on fulfilling their previous level of claims, might adversely affect the viability of the coalition. This is because in extreme situations satisfaction of conflicting claims requires considerable sacrifices on the part of negotiators even below the con-

Figure 8: Possible bias in using historical standards




N.B.

1. For the sake of simplicity it is assumed here that historical and extrapolated historical standards affect (compare with Figure 5) the constraint and target levels respectively. Also, any error is carried unchanged from the constraint to the target level and the resultant consensus level.

2. Consequently, under type I error the actual consensus level C' is set below the 'true' level C. Thus C-C' defines a margin which reflects under-exploitation of the environment. This parallels the slack B-B' which can provide a protective cushion in face of unexpected difficulties.

3. In contrast, type II error leads to over-exploitation of the environment; and as B'-B may represent shortage in face of difficulties, there is a potential danger for the continued existence of the coalition.

straint level they have set. In these circumstances, either the coalition members agree to lower their minimal requirement or the coalition may disintegrate.

The effect of external standards

The potential damage that can be caused by the detachment of historical standards from reality may be alleviated by using external standards. Reference to external standards may facilitate negotiators to lower their minimal requirements in the face of a harsh environment, enabling preservation of the coalition. Care should be taken, however, in selection and reliance on external standards, as their indiscriminate use may sometimes obscure the need for strategic change. According to Sutton,[24] a general decline in profitability in a group of specialised firms, may be followed by a general reduction of standards as the firms take their standards from each other. He further suggests that this simultaneous acceptance of lower standards of performance may have delayed the reorganisation of the U.K. shipbuilding and textile industries.

Applicability of external standards

For our purpose, external standards may be divided into two principal groups:

(i) voluntary reference to other comparable organisations

(ii) legal constraints imposed by legislation.

One potential danger of employing the first group was noted above; a related difficulty is associated with the firm's nature and characteristics. Its uniqueness may limit the firm's choice of external standard, the more unique it is the smaller would the population of reference firms be and less confidence could be put on the results. A way around this would be selective reference to other organisations according to chosen characteristics. Thus, a state-owned company, say in the chemical industry, may refer to local state-owned companies in the national, social and economic objectives, and to other comparable firms, even abroad, as regards its microeconomic activities. Thus, in the example cited above by Sutton, results might have been different if British shipbuilders would have referred to, for example, the Japanese shipbuilding industry. Of course, one must be careful not to carry the comparison too far, because apart from adoptable differences in investment strategy and organisational structure, there may well be cultural and other non-transferable differences affecting performance. The second group of external standards, i.e., legal constraints, may be another factor discouraging international comparison. A known example of how such differences may affect industries is the way anti-pollution standards for chemical plants in developed countries which are far more stringent than the ones in the less developed countries, have enhanced closure of plants in the former and their migration to the latter.

Of the groups of standards discussed so far, legal constraints are the most difficult to change and therefore are potentially the most destructive to the viability of the coalition. In practice, however, although it is very difficult, it is not impossible to change legal standards, but this largely depends on the bargaining power of the negotiators and their commitment to keep the coalition viable. Anti-pollution standards are well known as external standards, particularly in the chemical industry (see also Chapters 2 and 4), but there are other legal standards, such as those regarding employment which are external and may set the constraint level for a social objective associated with employment. It should be noted that treating legal standards in such a way differs from traditional corporate strategy formulations such as Ansoff and Argenti. where legal requirements are seen as a necessary evil whose main effect is to restrict the achievement of the central objective of profit. In our framework, legal standards are used together with other external standards (and with historical) to set the minimal requirement for obtaining social objectives in a socially responsible firm.

The importance of historical and external standards extends beyond their application in establishing the constraint level of objectives. In spite of the problems associated with their relevance, the fact that they are a relatively easily available source of data remains their main advantage. As such, they have a crucial role serving as a base on which standards relevant for setting a desired or target level of objectives can be derived.

### 3.5.5 Target Level of an Objective

The argument for employing reference standard in setting the target level of an objective is similar to the one justifying their use in setting the constraint level of an objective, and repeating it here may be omitted. However, as was suggested earlier, past experience may reasonably serve as an acceptable minimal requirement on performance. The question is, what are the appropriate standards for determining a target level of an objective. If, as Loasby argues, the planning standards are derived from plans, then their use for our purpose appears problematic. The nature of the difficulty is understood if one accepts that plans are normally drawn on the basis of objectives which are to be determined by reference standards. Thus, use of planning standards derived from plans for defining objectives may imply a fairly complicated iterative process yielding dubious results.

Since feasibility is an important ingredient at the beginning of the planning process, planning standards should rely on some factual standards. Therefore, as an alternative to the above interpretation of planning standards, the present study suggests regarding them as some weighted extrapolation of historical and external standards. In order to avoid confusion with the former view on planning standards, it is proposed here to call the extrapolated standards - intentional standards - as they are meant to reflect tentative intentions of negotiators to be later modified during the bargaining process.

#### 3.5.5.1 Intentional Standards

In our framework, intentional standards are seen as some weighted function of at least two groups of factors:

(i) the negotiator's tastes, attitudes and interpretation of environmental conditions.

(ii) historical and external standards.

It is proposed that the second group of factors may provide the basis for extrapolation, but its extent and magnitude would be largely determined by the first category. The resultant intentional standard can then be employed in setting the target or desired level of an objective.

Admittedly, viewed in this way, intentional standards require reliance on experience which is associated with the problems of relevance mentioned previously in discussing historical standards. However, even in modern planning which may be far more sophisticated than a simple extrapolation of history, some reference to the past appears to be unavoidable. On the one hand, planners maintain that the progress of management science facilitates transfer of cost items to the engineered category (predictable from a knowledge of required outputs, such as material requirements) from the managed category (where the requisite levels, for instance, of welfare expenses, are unknown and hence subject to managerial discretion). But on the other hand, as Loasby has noted, this trend should not be allowed to disguise the fact that standards for engineered costs are normally derived from historical experience, because it is much easier to establish what a particular operation has cost than what it should ideally cost.[25]

Therefore possible problems of relevance (similar to the ones discussed for historical standards) may be encountered in handling intentional standards. These problems, which stem from reliance of both on the past, may be mitigated by using imaginative standards or innovative standards.

### 3.5.5.2 Innovative Standards[26]

Suckling proposed the idea of imaginative standards that suggest hypotheses through a process involving a creative leap, which at best, can be rationalized but not analyzed. Loasby asserts that such new hypotheses can generate experimental problems for science and therefore considers imaginative standards to be effective problems generators.[27] In a similar way, such standards may set new target levels for objectives or even generate new objectives. By definition, new objectives have no historical or intentional standards and therefore the establishment of a constraint level is not straightforward. A constraint level for a totally new objective can be established only after some experience is accumulated.

In a science-based industry like the chemical industry, innovative standards are of particular importance, as they take into account technological change which may indicate directions of development which can upset target levels based on intentional standards discussed earlier.

Consider for example, a state-owned bromine producer who is restricted to the profitable (or at least break-even) manufacture of his product (for reasons discussed in Chapter 2). Such a producer will be interested in facilitating long-term demand and profitable growth for his product. According to the target-constraint approach, suggested in this chapter, the constraint level of such a growth objective may be set by both historical and external standards, whereas the target level would be established by a combination of intentional and innovative standards. Intentional standards may incorporate some anticipated moderate technological developments, but it is suggested that if innovative standards are to be of any significance, they must rely on technological change.

### 3.6 Application of the Framework to a State Owned Israeli Bromine Producer

The notion of technology based growth suggested by the use of innovative standards has particular significance for a specialized producer in a declining or slow growth industry. Consider such a real world producer, namely an Israeli manufacturer of bromine.

The main objectives of the state-owned Israeli bromine producer are presented in Figure 9.

Our purpose here is to discuss briefly directors' attitudes and by using the schema, to point out the principal relationships among objectives.

#### 3.6.1 Directors' attitudes

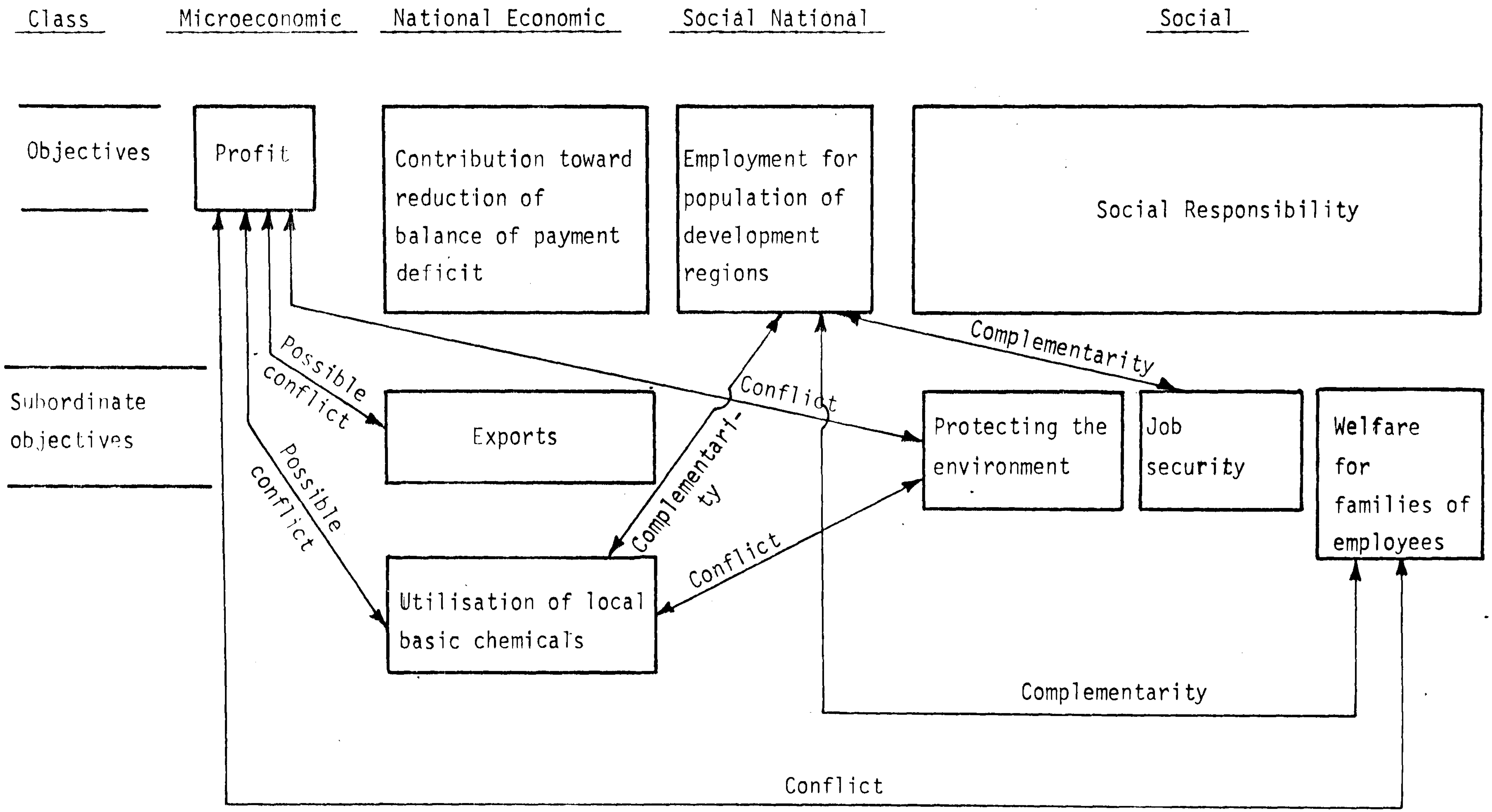
A summary of interviews with the company directors is presented in Appendix A. These interviews reveal the conflicting views of directors concerning objectives such as providing employment in the social national category, or balance of payments objective in the national economic category.

But directors did not attend to the potential conflict between all categories. For instance, the widely accepted objective of protecting the environment is in constant conflict with profit and to a certain extent with the other objectives as well. See a summarised representation of main relationships in Figure 9.

This apparent unawareness of all potential conflicts, which perhaps may be attributed to the vague and implicit presence of the firm's objectives, has its value in avoiding disruptive antagonism among directors, and between them and government. On the other hand, it was found during interviews that ambiguity and vagueness are disturbing for some executives, particularly at middle management, who would have preferred clearly defined and easily identifiable goals. This finding fits in with Christensen's view that roles of the middle level manager must be known and appropriately supported.[28]

Similarly, the findings of a NEDO report in Britain (see p. 19) revealed that governments' and directors' conflicting interpretation of objectives may result in uncertainties which have led to situations where a decision making vacuum was formed.[29]

Figure 9: A Summarised Form of the Producer's Principal Classes of Objectives and their Main Relationships



### 3.6.2 Relationships among Objectives

Earlier in this chapter, we discussed general properties of Williamson's managerial discretion models. Two models have been suggested, the staff model and the emolument model. A different relationship with profit was described for each. Thus the staff model was seen as a concave function having one maximum and the emolument model was conveniently described as a linear function having a negative slope (see p. 51). It is suggested in this work that national and social objectives can be classified into two basic groups, one resembling the staff model and the other behaving similarly to the emolument model. Figures 3 and 6 represent graphically the two basic relationships.

### 3.6.3 Concave Relationship

The national social objective of providing employment belongs to the group exhibiting concave relationship with profit. The argument here exactly parallels the one presented in our earlier discussion on Williamson's staff model, in addition to pressure from government to adopt this objective. The same basic relationship can be shown for the national economic objective of utilisation of bromine resources. In general, increases in exploitation of natural resources are associated with some increases in productivity and consequent rises in discretionary profit. But at some level of exploitation, the marginal costs of an additional unit of output may outweigh its marginal revenues and profit will decline.

Given that, as already has been argued in this chapter, the firm is confined to activities associated with the defined area of bromine and compounds production these activities provide the framework within which the formerly mentioned objectives of exports and employment can be satisfied. Considering the various ways in which these objectives contribute to both governmental and managerial satisfaction and prestige, it would be reasonable to expect that they affect positive preference of management and government toward utilisation of bromine resources.

### 3.6.4 Linear Relationship

Finally there is a group of linear relationship with profit which will be represented here by the social responsibility objective of protecting the environment.

Similarly to Williamson's emoluments model, this category of objectives is at best associated with zero productivity, hence, any increase, say, in anti-pollution measures will involve costs that will cause a reduction in discretionary profit. The resultant relationship may be conveniently described as linear with a negative slope. Again prestige, but also genuine care for the environment, may induce a positive expense preference toward this kind of objective.

### 3.6.5 A Concluding Note

This treatment which resembles Williamson's approach is open to similar criticisms which were presented earlier when Williamson's staff model was discussed (see p. 60-62).An additional issue for criticism may be Williamson's attitude toward technological change; at best, it is implicitly included in his category of environmental changes, and as such considered to be exogenous to the managerial objective function.

In our schema for setting target and constraint level of an objective, technological change is introduced mainly by the use of innovative standards. However, the value of Williamson's approach for our purpose is in indicating the nature of the relationship between objectives and perhaps predicting directions of variation in setting the actual level of achievement of each objective during the bargaining process when objectives have to be traded-off. Magnitudes however would depend on the bargaining power of negotiators and the way in which they perceive the real state of affairs. In general, it is expected that the actual level of an objective would be some weighted compromise between its constraint level, target level and the bargaining power of its promoter(s) relatively to other members of the coalition.

### 3.6.6 The Bromine Producer's Objectives in the Target-Constraint Approach

#### Introduction

The underlying assumption here is that it is enough to attend to a firm's principal objectives in order to obtain a generalised consensus between senior decision-makers at the strategic level of decision-making. It may be argued, of course, that such a policy would tend to conceal complex interrelationships and inconsistencies among lower level objectives. Admittedly using our schema to resolve all conflicts simultaneously would be a very complicated task indeed, and therefore Cyert & March's measures such as sequential attention to goals and local rationality, which find their justification in the phenomena of partial ignorance and bounded rationality, must be employed in our framework, remembering that it does not seek to resolve all possible conflicts. It is believed that, as Loasby[31] has pointed out, "Full consensus on objectives is not necessary to keep an organisation together; nor is it necessary to effective decision making...Even the individual need not fully reconcile his internal conflicts, since neither the interdependencies in the complex situation to which it is to be applied can be fully understood, or properly taken into account even if they were. Schizophrenia is indeed a problem, but moderate inconsistency is not. If this is true of the individual, then surely it must be true in the greater complexity and amid the additional obscurities of decision making within an organisation."

In a way, this attitude summarises the implicit logical basis for our target-constraint approach.

#### 3.6.6.1 Setting Constraint Level on the Producer's Objectives

Historical and external standards

It appears that the outlined objectives, i.e., utilisation of bromine resources, exports, employment, environmental protection and profit, can all draw on historical standards such as previous years' achievements. The dangers in the possible bias of historical standards were discussed earlier in this chapter (see p.67 ). It was not only suggested to use external standards to alleviate those risks, but also to be aware of errors in their indiscriminate application to firms with unique assets.

Indeed the firm's characteristics as a state-owned chemical company obliged to be based on local bromine resources make it difficult to find appropriate external standards. Yet it is not an impossible mission, if selective reference is made to various domestic sectors of the economy and to comparable bromine producers abroad. Thus, external standards for employment may be obtained from local state-owned companies; external standards for environmental protection may be relatively easily based on legislation. But objectives such as utilisation of bromine resources and profit, which are associated mainly with exporting particular products, do not appear to favour domestic comparisons, and external standards may be sought abroad among chemical companies producing similar products.

However, our earlier discussion in this chapter on external standards suggests that factors such as cultural differences and local economic climate make detailed international comparisons a very complicated and somewhat risky task. Hence, the costs and dangers associated with search for and detailed comparison to external standards should be carefully weighed against those of reliance on historical standards alone.

#### 3.6.6.2 Setting the Target Level for the Producer's Objectives

##### Intentional and innovative standards

As was argued previously in this chapter, intentional standards are based in a sense on historical standards and comprise similar possible bias. In their reliance on past experience for extrapolations, they fit in with conventional corporate strategy models. Thus our use of innovative standards which imply attainment of objectives through technological change, represents a departure from such models. Innovative standards are not to be extrapolations of the past; true, they often have to rely on the past for certain facts, but they, unlike intentional standards, should attempt to change these facts and not allow them to set biased limits on target levels. Admittedly, the more daring the innovative standards are, the wider will be the relevant time horizons; but even if they are seen by cautious observers as unrealistic, they may have value in "inhibiting the subtle censorship of current ideas."[32]

##### The target level for bromine production

As a state-owned enterprise restricted to a defined area and because it is a specialized bromine producer relying on an extremely rich bromine source (see last section in Chapter 4), the attainment of its objectives would largely depend on the inherent potential of this material (see Appendix A).

Having accepted the centrality of the production objective for the Israeli bromine producer, there remains the need to establish the target level, in this instance, using intentional and innovative standards.

Intentional standards for bromine production would reasonably refer to current world demand and usually would involve some extrapolations. Such projections are presented in Chapter 4 where world bromine demand is forecasted to grow at an average annual rate of 1.7% from 310000 tpa in 1978 (Table 3, p. 99) to 349000 tpa in 1985 (Table 7, p.103). Growth with the market at this rate implies increasing the firm's production capacity from 50000 tpa in 1978 (Table 6,p.102) to about 60000 tpa in 1985.

Innovative standards, on the other hand, would detach themselves from present estimates and would insist on full utilization of the entire bromine production potential - over 1 million tpa of bromine. This production level is regarded by top management (see Appendix A p.227) as the central long-term objective of the corporation in spite of the fact that it exceeds projected world demand (which according to the most probable estimate of Table 3 will be 450000 tpa in 2000).

In practice, however, the long-term target level served to modify upwards the production level set above by intentional standards. The modified level ultimately decided upon by management - the consensus level-requires production of about 100,000 tpa bromine in 1985 (Table 11, p. 111).

It is quite obvious that the considerable gap between the company's long-term target and the projected world demand for bromine cannot be bridged without technological change that will result in major changes in the end-use pattern of bromine.

## 3.7 Summary and Conclusions

In this Chapter, it is argued that conventional corporate strategy models as represented by Ansoff, do not adequately treat the reconciliation of objectives. This inadequacy stems from the primary role assigned to profit which does not imply problems of reconciliation, since in any potential conflict profit will be preferred. However, other authors in management literature such as Lowes and Sparkes, who regard economic and social objectives as equally important, do recognize the need for reconciliation, but their method is criticised as impractical. This study therefore suggests that both the behavioural approach proposed by Cyert and March, together with the trade-off mechanism which can be extracted from Williamson's managerial discretion models, may be incorporated into a relatively simple and flexible framework for balancing conflicting objectives. The essence of the schema is setting objectives at two levels, a minimal requirement or the constraint level, and a desired achievement or the target level of the objective. The difference between the two represents the margin within which conflicting claims might be satisfied.

This study has concerned itself with the question of what might be starting points for establishing the target and constraint levels, and suggested the use of reference standards. These have included historical and external standards for the constraint level, and intentional and innovative standards for the target level.

It was argued that innovative standards are of particular importance to science-based industry as they may suggest important opportunities through technological change. This has particular significance for a specialized firm in a declining or slow-growth industry. The present study maintains that the best way to illustrate this point is by providing a specific example. Thus, a state-owned Israeli bromine manufacturer was selected as an illustration of this type.

On the basis of interviews with management of the bromine producer it has been found that the profitable production of bromine is seen as the major objective of the company. It is argued that a bromine production target level set by innovative standards is well above projected world demand level.

This chapter tentatively concludes that only technological change can reduce the gap between those two levels. As far as the consensus level is concerned, no conclusion can be made without an examination of the bromine industry.

This is carried out in Chapter 4, where general factors affecting growth in the bromine industry are outlined and the specific case of the Israeli bromine manufacturer is noted. Consequently, the imperative need for seeking growth through technological change is recognized and this problem is discussed in Chapter 5. The discussion then leads to Chapter 6 where a technological growth tree is formulated and applied to bromine.

# CHAPTER 4

# THE BROMINE INDUSTRY

## 4.1 Introduction

We have seen in the previous chapter that the existence of a gap between innovative standards and intentional standards signified that growth will mainly come through technological change. This point is best illustrated by applying the concept to a specific industry - in this instance that of the bromine industry and an Israeli bromine producer in particular. It will be demonstrated that in the latter case there is an imperative need to seek such growth through technological change.

The chapter commences with an enquiry into the bromine industry and discusses the factors effecting growth, such as environmental problems, effect of energy, and availability. Thereafter, the special case of the Israeli bromine producer is considered.

## 4.2 Technical Background

Bromine is a nonmetallic element of the halogen family. It is a toxic fuming liquid at ordinary temperatures and pressures. The diatomic nature of bromine persists throughout the solid, liquid and gaseous phases. Its physical and chemical properties are between those of chlorine and iodine. Some physical and chemical properties of practical importance are briefly discussed below:[1]

### Physical properties[2]

The most important physical property of bromine is its high density. At 20°C, it is 3.12. The high density characteristics of bromine compounds can be advantageously applied where heavy and clear fluids are required. For example, calcium bromide in aqueous solution was introduced as a dense fluid product for use as oil well packs and completion fluids.

Another important property is its relatively large atomic radius (1.12 Å as compared with 0.97 Å for chlorine). This makes bromine a bulky reactant and can cause significant steric effects in aromatic substitution reactions.

Chemical properties

The atomic number of bromine is 35. The arrangement of the electrons is as follows: 2 in the K shell, 8 in the L shell, 18 in the M shell and 7 in the N shell. $1S^2 2S^2 2p^6 3S^2 3p^6 3d^{10} 4S^2 4p^5$. This differs from the corresponding inert gas (Kr) configuration by only one electron, so that the octet concept applies. And for the sake of simplicity in our brief discussion, it will be used to explain bromine's important chemical characteristics. The bromine atom approaches the octet configuration by gaining a single electron and forming a negative bromide ion.

This tendency to gain an electron (electronegativity) accounts for its oxidizing power. It is therefore a corrosive material which reacts with metals (electron donors) to form bromides. This causes problems of handling and transportation of bromine. Only metals that react in such a way with bromine to form an insulating bromide layer will be suitable for bromine containers, for example, lead is accepted for this purpose.[3]

As regards organic compounds, the electron affinity of bromine accounts for its addition to unsaturated or electron-rich centers of a molecule, or its substitution for an atom or a group. Other characteristic reactions include simple oxidation of certain functional groups and catalytic reactions of bromine in which the latter does not appear in the final product.[4]

The organic reactions of bromine with substrates that are constituents of living matter (e.g., aliphatic acids, aromatic amino acids, etc.) can cause changes [illegible] properties of individual cell components, and be held accountable for gross, non selective injury to living tissues.[5]

The nature of the participation of bromine in organic reactions results in a mechanism of flame inhibition by bromine. With a premixed hydrocarbon-air flame, for example, bromine reduces the rate of the chemical reaction of the flame, thereby reducing the burning velocity.[6] Chlorine compounds resemble their bromine analogues in this respect, but the latter are more effective. One bromine atom per molecule reduces flammability about as much as two chlorine atoms.[7]

## 4.3 The Major sources of Bromine[8]

Bromine is a highly reactive element and exists in nature only as the bromide. The most readily recoverable form of bromine occurs in the hyrosphere as soluble bromide salts. The largest potential source of bromine in the world exist at the oceans. Reserves are virtually limitless but bromide concentration is low-estimated at 0.065g/L.

The largest measureable reserves estimated at over 1 billion tonnes are at the Dead Sea - an average bromide concentration of nearly 5g/L.

According to the U.S. Bureau of Mines,[9] U.S. resources have not been quantitatively measured, but large areas of underground brine with high bromine content are located in Arkansas and Michigan. Concentration of bromide in the former is about 5g/L and 1.3 g/L in the latter.

It may be concluded that there are ample extractable reserves in the world of bromine and this is a 'resource abundante' commodity.

## 4.4 Key Points in Bromine Production[10]

The key factors of bromine recovery processes are the selective separation of bromide from chloride and the removal of small concentrations of bromine from large volumes of aqueous solution. The selective oxidation of bromide in the presence of large amounts of chloride is possible because of the difference in their reduction potentials.

### 4.4.1 Oxidation of Bromide Ion

Consider the following reduction processes for both chlorine and bromine:

$$\tfrac{1}{2}\ Cl_2(g) + e^- \rightarrow Cl^{(-)} \qquad E^o = +1.356V$$

$$\tfrac{1}{2}\ Br_2(g) + e^- \rightarrow Br^{(-)} \qquad E^o = +1.065V$$

$E^o_{Cl}$ and $E^o_{Br}$ represent the standard electrode redox potential for chlorine and bromide respectively. The difference between the two, $\Delta E$ is given by the following equation:

$$\Delta E = E^o_{Cl} - E^o_{Br} = 1.356 - 1.065 = 0.291$$

This positive value of $\Delta E$ means that chlorine is the stronger oxidant and provides the driving force of the following reaction:

$$Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$$

The bromine released by this reaction is quite volatile, can readily be driven out of the solution and in this way can be recovered.

In fact, chlorine is the most convenient and economical oxidant for bromide and is employed in all current methods of bromine production.

### 4.4.2 Bromine Production

The two major processes are the 'steaming out' (or Kubierschky) process and the 'blowing out' (or Dow) process.

The 'steaming out' process consists of simultaneous chlorination and steam blowing. Steam heated brine is oxidized by chlorine. The liberated bromine is then steam-distilled.

The 'blowing out' process consists of:

(1) chlorination of the brine

(2) air blowing of the liberated bromine

(3) separation of the outblown bromine from the carrier-air by chemical absorption

(4) Liberation of the absorbed bromine

(5) further purification

Steam is suitable when the raw brines contain more than 1 g/L of bromine, whereas air is used when the source is as dilute as sea water. In fact, steps (4) and (5) of the blowing out process may be looked upon as a steaming out plant fed by a concentrated bromide solution obtained in step (3).

### 4.4.3 Major Costs of Production*

The costs of bromine production depend on the raw material (brine) and on the process used.[11]

For instance, in the steaming-out process and assuming 50 per cent heat exchange in brine heating, about 30 - 40 tons steam per ton bromine from a brine of 2g/L bromide concentration are needed. The second important item is chlorine of which at least 550 kg per ton bromine would be needed. In a plant based on the blowing-out process, the chlorine bill would be twice because of the need to liberate the bromine twice, first from the brine and later from the absorbing solution. Also, a plant using sea water faces additional costs due to mineral acid and electricity as compared with a concentrated brine plant using the steaming-out process. Thus the richer the brine, the lower the costs of production.

* This issue is further considered in section 4.9.2.1

## 4.5 End Uses[12]

Bromine is used in several areas. Figures available for the U.S. market are presented below:

Table 1: Bromine Demand by End Use Category

000 tonnes of bromine consumption (%)

| USE | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|---|---|---|---|---|
| Fuel additives | 110.1(71.0) | 102.0(67.3) | 122.2(75.2) | 115.5(70.0) | 108.9(66.2) | 98.0(63.2) | 109.7(61.3) | 102.5(60.3) | 100.4(58.7) | 83.0(48.0) |
| Sanitary Preparations | 21.7(14.0) | 21.4(14.0) | 16.2(10.0) | 16.8(10.2) | 16.5(10.0) | 16.9(10.9) | 17.5( 9.8) | 18.0(10.6) | 16.2( 9.5) | 28.2(16.3) |
| Fire Retardants | 7.8( 5.0) | 10.7( 7.0) | 11.4( 7.0) | 23.6(14.3) | 25.4(15.4) | 21.7(14.0) | 26.3(14.7) | 28.9(17.0) | 31.8(18.6) | 50.3(29.1) |
| Other | 15.5(10.0) | 17.9(11.7) | 12.6( 7.7) | 9.1( 5.5) | 13.8( 8.4) | 18.4(11.9) | 25.5(14.2) | 20.6(12.1) | 22.6(13.2) | 11.5( 6.6) |
| Total | 155.1 | 153.0 | 162.4 | 165 | 164.6 | 155.0 | 179.0 | 170.0 | 171.0 | 173.0 |

Source: Minerals Year Book, U.S. Dept. of Interior, Bureau of Mines, U.S. Govt. Printing Office, Washington D.C. 1981, p.4.

Table 2: U.S. Bromine Output According to Use in 1980

| USE | 000 tonnes of bromine consumption | percentage |
|---|---|---|
| Ethylene dibromide | | |
| Fuel additives | 52.2 | 37.8 |
| Agrochemicals | 5.9 | 4.3 |
| Flame retardants | 25.0 | 18.1 |
| Clear fluids | 25.0 | 18.1 |
| Methyl bromide ag fumigant | 10.4 | 7.6 |
| Sanitary Preparations | 1.8 | 1.3 |
| Other | 17.7 | 12.8 |
| | 138.0 | 100.0 |

Source: The report of Kidder, Peabody & Co., May 1982, p.27.

Table 2 is more detailed as it specifies agrochemicals and clear fluids which do not appear separately in table 1, presumably they are included in the 'other' category.

Consumption patterns, in other countries, are likely to be similar to the USA though different emphasis, e.g. Western European countries with a large plastics industry are likely to use more bromine in flame retardants. Japan is an exception, since there the most important consumer of locally produced bromine is agrochemicals (60% of total demand) 15% fire retardants, and 25 % others.[13]

### 4.5.1 Fuel Additive

The bromine compound used as a fuel additive is ethylene dibromide (EDB) which is also used in other areas (in particular, agrochemical, see later 4.5.2). However, as a fuel additive, EDB reacts with the lead deposited in an engine using leaded petrol to form lead bromide which is volatile enough to be expelled with the exhaust gases.

The tables above show that EDB in this application was the largest end-use market for bromine until 1980. But the bromine consumption is declining since 1976 both in relative and absolute terms. This is due to the phase down of the use of lead in petrol mandated by the Environmental Protection Agency (EPA) in the U.S. Furthermore, a recent report by Mannsville Chemical Products[14] argues that the use of leaded petrol in the U.S. will probably be essentially phased out by 1990, effectively eliminating the use of EDB in petrol.

A more optimistic forecast is given in a U.S. Bureau of Mines publication.[15] It estimates a bromine consumption of 34000 tpa in 2000, but it does not state its assumptions. A more recent report[16] assumes, on the one hand, no further reduction in allowable lead content and a 0% to 2% annual decline in U.S. petrol consumption between 1980 - 1986. On the other hand it mentions the less likely possibility that the lead limit could be revised upward. On this basis it reaches the forecast of 34000 tpa of bromine in 1986, much sooner than the Bureau of Mines.

In conclusion, although these forecasts disagree about rate and size of bromine consumption in the fuel additive market, they agree about the trend of decline. This trend will lead bromine to excess capacity pressures for integrated bromine- EDB producers who will have to compete in other bromine end use markets. Thus, the resulting increased competition for established producers in those end-markets may well trigger the search for new bromine outlets.

### 4.5.2 Agrochemicals

In table 1 these are lumped under the "other" category, but in table 2 this outlet consumes 16300 tpa of bromine and constitutes nearly 12% of total bromine demand in 1980. Bromine compounds are used in agriculture mainly as soil and space fumigants. The most important ones are ethylene dibromide (EDB), methyl bromide and dibromochloropropane (DBCP).

EDB was used as a soil and space fumigant, but Mannsville Chemical Products[17] has recently reported that the Environmental Protection Agency (EPA) plans to ban its application as space fumigant and approve it only as a soil fumigant. The Kidder, Peabody report[18] points out that this EPA plan offers an opportunity in the soya bean market where the traditional fumigant, dibromochloropropane, was banned in 1979. Assuming full replacement of DBCP, the Kidder, Peabody report estimates bromine consumption in this outlet at 12300 tpa in 1986 or an annual average growth potential of over 12%.

The other fumigant, methyl bromide, is much broader in application than EDB, but is relatively expensive in use. The Kidder, Peabody report expects its historical 6% annual growth rate to continue and forecasts bromine consumption of 14500 tpa in 1986. This estimate is optimistic as it ignores the possibility pointed out by the U.S. Bureau of Mines publication,[19] that use of methyl bromide could be banned in the future for environmental reasons.

In summary, the Kidder, Peabody report expects agrochemicals to grow in importance as a bromine end-market, but this conclusion should be treated with some reserve because environmental considerations could inhibit the use of brominated agrochemicals in the future.

### 4.5.3 Fire Retardants

The fire retardant market is strongly influenced by laws and regulations. This facilitates market growth on one hand since plastic and synthetic fibre manufacturers would have used fire retardants to a lesser extent if its use was not enforced by legislation. On the other hand, other regulations will ban the use of fire retardants associated with health hazards. A famous example in the industry is tris (dibromopropyl) phosphate which was recommended for banning by the National Cancer Institute (NCI) in the U.S., and 1976 and 1977 witnessed a major decrease in the use of tris in textiles.[20]

Nevertheless table 1 shows that increase in use of other brominated fire retardants must have compensated for the loss of demand of bromine by tris.

Table 1 and 2 show that flame retardants have declined sharply both in absolute and relative terms, due on one hand to the depression in the U.S. economy[21] and the increase in importance of agrochemicals and clear fluids, on the other hand.

The Kidder, Peabody report, however, argues that due to regulations, growth will continue to be at an annual rate of 10% reaching 44000 tpa of bromine consumption in 1986.[22] It should be noted, however, that this is still lower than the 1979 figure in table 1.

### 4.5.4 Sanitary Preparations

Bromine and its derivatives perform well in this area. Thus, bromine has been recommended for use in water sanitation as a substitute of the traditional chlorine.[23] This is because the chlorine reacts with amines to produce stable chloramines which have been reported as toxic compounds. The bromamines are much less stable and hence residuals are lower.[24]

Because bromine is safer than its substitute, the U.S. Bureau of Mines publication sees it as a growing area and forecasts a probable use of 45400 tpa of bromine in 2000 - an annual average growth rate of 4.8% from 1978.

The Kidder, Peabody report[25] on the other hand concludes that although bromine derivatives are safer, their higher price compared with their substitute holds back their wide acceptance. Since they find it difficult to balance the two opposing influences, they maintain that bromine consumption in this field could be anywhere between 2000 tpa - 10000 tpa of bromine consumption in 1986. The report assumes a probable figure of 7700 tpa.

### 4.5.5 Clear fluids for the oil industry

The oil industry is a fairly new outlet for bromine. The limited oil reserves together with their frequent price increases are a strong incentive for utilizing inferior oil wells. These cannot be utilised by using ordinary drilling fluids, and calcium bromide has been introduced as a technically superior substitute. However, its current high production costs hold back its further diffusion.

Table 2 shows that in 1980 this outlet became equal in importance to fire retardants, whereas in table 1, it was still under the "other" category.

Indeed, the Kidder, Peabody report[26] maintains that by 1986 clear fluids should be the largest bromine consumer, accounting for almost one third of total bromine consumption in the U.S. reaching 68000 tpa of bromine. However, the report does concede that the projection is most uncertain. It points out the following reasons:

(i) The costs associated with clear fluids use in oil well drilling are relatively high.

(ii) Experimentation to find non-brominated substitutes is taking place.

(iii) The uncertainty regarding the future direction of oil prices and drilling activity is high.

### 4.5.6 Early Uses

Traditional uses (which in their time initiated the industrial production of bromine) include photography and pharmaceutricals. In both tables 1 and 2, these uses and others are lumped together under the "other" category.

The U.S. Bureau of Mines publication[27] briefly notes that these uses are not likely to decline as they do not present environmental problems. The Kidder, Peabody report also states briefly that this segment of bromine consumption will grow at an average annual rate of 2%, the same as the U.S. GNP, reaching about 20000 tpa of bromine consumption in 1986.

4.5.7 Interim Conclusion

In summary, the level of bromine consumption in its various end-use categories is influenced (apart from general economic climate) by two factors:

(i) The degree to which the industry will be able to overcome environmental problems and produce safe products.

(ii) The degree to which the industry will manage to reduce its costs of production.

The uncertainty associated with these two factors is considerable as is evident from the disparity between various forecasts pertaining to almost the same period.

On the one hand, the U.S. Bureau of Mines forecasts an average annual growth rate of 1.3% between 1978 and 2000 in the U.S. In 1986 it therefore projects (from a basis of 170600 tpa in 1978) a consumption of about 189000 tpa bromine. This is in good agreement with the Kidder, Peabody report (summing up bromine consumption in all its end-use applications) forecast of about 186000 tpa in 1986 in the U.S.

In contrast, the report by Mannsville Chemical Products[29] gives a total of only 113500 tpa bromine consumed in the U.S. in 1985, even below the depressed level of 1980 (see table 2).

The U.S. Bureau of Mines[30] expects that, in some countries, consumption of bromine will decline in some of its end-uses, particularly in fuel additives similar to the U.S.A. But it argues that the other uses are likely to expand; therefore it estimates an annual growth rate of 2.2% for the rest of the world. Thus, on a basis of 139000 tpa in 1978, it forecasts about 165000 tpa of bromine consumption in 1986 for the world outside the U.S.

It should be noted however the the U.S. Bureau of Mines is cautious in its forecasts and provides a wide forecasting range as is evident in the following table:

Table 3: Summary of forecasts of U.S. and the rest of the world

Bromine demand in 000 tonnes.

| Year/ Area | 1978 | 2000 Forecasting Range Low | High | Probable | Average Annual Probable Growth Rate 1978 - 2000 (Percent) |
|---|---|---|---|---|---|
| U.S. | 171 | 70 | 295 | 226 | 1.3 |
| Rest of the World | 139 | 136 | 295 | 224 | 2.2 |
| Total | 310 | 206 | 590 | 450 | 1.7 |

This wide forecasting range clearly reflects the uncertain situation of demand for bromine.

It remains now to examine the supply side - for this we turn to the next section.

## 4.6 World Bromine Production Capacity

The U.S.A. and Western Europe constitute the two major bromine markets. This is shown in table 4 below:

Table 4: 1980 Production capacity and demand in U.S.A. and Europe

(000 tonnes)

| | Production Capacity | Demand |
|---|---|---|
| U.S.A. | 300 (1) | 130 (1) |
| W. Europe | 58 (2) | 95(e) (3) |

(1) Based on Chemical Products Synopsis 1982

(2) From: U.S. Bureau of Mines, U.S. Government Printing Office 1981

(3) An estimate based on Kidder, Peabody's data 1982

The table also shows that whereas the U.S.A. consumes a fraction of its production capacity, W. Europe consumes more than it can produce.

### 4.6.1 The Main Producers

The U.S.A. producers are listed in the table below:

Table 5: U.S.A. Production Capacities

| Producer | Bromide Concentration g/L | Capacity (000 tonnes) 1980 | | 1985 |
|---|---|---|---|---|
| Great Lakes | 4.0 - 5.0 | 70 | | |
| | 4.0 - 5.0 | 36 | | |
| | | | 106 | 106 |
| Arkansas Chemicals | 4.0 - 5.0 | 23 | 23 | 23 |
| Ethyl Corp. | 4.0 - 5.0 | 73 | 73 | 73 |
| Dow Chemical Corp. | 4.0 - 5.0 | 50 | | |
| | 1.5 - 2.0 | 39 | | |
| | 1.5 - 2.0 | 9 | 98 | 98 |
| Total | | | 300 | 300 |

Sources: Kidder, Peabody & Company report 1982 p.18

U.S. Bureau of Mines, U.S. Government Printing Office 1981, p.2.

The table shows that the large U.S.A. bromine market is shared by only four producers, two of them account for nearly 70% of U.S.A. bromine production capacity. Another characteristic of the U.S. market is that more than 80% of capacity is based on relatively rich (4-5 g/L) bromine sources.

In contrast, bromine production capacity in the rest of the world is shared among many producers. Another characteristic is that most of the known concentrations are low. Israel is an exception with an extremely high concentration of bromide. This is shown in the table below:

Table 6: World Bromine Producers

| Producer | Country | Concentration g/L | Capacity (000 tonnes) 1978 | Capacity (000 tonnes) 1985 |
|---|---|---|---|---|
| Associated Octel Corp. | U.K. | 0.065 | 31 | 31 |
| Mines Domaniales de Potasse d'Alsace SA | France | NA | 5 | 5 |
| Octel-Kuhlman | France | 0.065 | 15 | 15 |
| SAI Bromo Italiano | Italy | 0.065 | 0.6 | 0.6 |
| K & S | W. Germany | NA | 5 | 5 |
| NA | Spain | 0.065 | 1.4 | 1.4 |
| NA | India | 0.065 | 0.4 | 0.4 |
| Dead Sea Bromine Ltd. | Israel | 12.0 | 50 | 100 |
| Toyo Soda Mfrs. | Japan | 0.065 | 12 | 12 |
| Hukuriky Salt & Chemicals | Japan | 0.065 | 1 | 1 |
| Ashai Glass Company | Japan | 0.065 | 1 | 1 |
| NA | USSR | NA | 16 | 16 |
| Total: | | | 138.4 | 188.4 |

The table was compiled on the basis of the following sources:

(a) Bromine World Survey of Production Consumption and Prices; Roskill Information Services Ltd., London 1975.

(b) Bromine, U.S. Bureau of Mines, U.S. Government Printing Office 1981

(c) Kidder, Peabody & Co. 1982

## 4.7 The Overall Scene[31]

The demand forecasts and the projected production capacities mentioned earlier in this chapter can be summarized in the following table:

Table 7: Demand and Production Capacities of Bromine in 1985

( 000 tonnes)

| | Demand(1) | Production Capacity(2) |
|---|---|---|
| U.S. | 187 (a) | 300 (a) |
| Rest of the World | 162 (b) | 188 (b) |
| Total | 349 | 488 |

(1) The demand figures are based on the forecasts presented in section 4.5.7:

(a) The probable projection of the U.S. Bureau of Mines and the optimistic forecast of Kidder, Peabody & Co., (the pessimistic forecast of Mannsville Chemical Products is ignored).

(b) The probable figure projected by the U.S. Bureau of Mines.

(2) The production capacities are based on: (a) table 5 (b) table 6

Thus even the optimistic forecasts indicate an over-capacity situation in the world bromine industry.

It has already been noted (see also Table 4) that the U.S. and W. Europe are the principal bromine markets. Traditionally, however, the two markets were always almost entirely isolated for two principal reasons:

1. The problems associated with elemental bromine marine transportation.
2. The integrated market structure of bromine, ethylene dibromide and oil.

However, in spite of these barriers, it is most likely that the large excess capacity of the U.S. producers coupled with their reliance on their relatively concentrated bromine source (compare tables 5 and 6) will encourage them to attempt to enter the European market. Thus, in order to find overseas markets, the ban on elemental bromine export that the American Government had imposed on U.S. producers, has now been lifted.[32] By contrast, European producers, because of their reliance on dilute sources are scarcely likely to attempt to compete in the American market in spite of the projected excess of production capacity. Competition is therefore likely to take place mainly in Europe.

## 4.8 Interim Conclusion

It has been argued that not only there is a virtually unlimited availability of bromine in the world but also a considerable disparity between the production potential and the relatively limited consumption pattern of bromine. The latter is dominated by two major factors: environmental awareness and costs of production.

Environmental and safety considerations exhibit a contradictory influence on the future level of consumption of bromine. On one hand, some bromine compounds are banned due to suspected toxicity.

On the other hand, fire safety regulations may favourably effect the demand for bromine due to its fire retardation ability.

Costs of production are dictated by costs of energy and the concentration of bromide in the bromide source. An increase in energy costs will contribute to higher production costs; however, ceteris paribus, the higher the bromide concentration, the lower will be the production costs. Consequently, generally rising energy costs will favour producers having a rich source of bromine.

The problem of selecting an appropriate strategy in these circumstances can be illustrated by reference to a particular bromine producer. This is discussed in the following section.

## 4.9 The special case of the Israeli producer - Dead Sea Bromine (DSB)

### 4.9.1 Introduction

DSB is a state owned company which does not publish financial reports. Furthermore, its management is most careful not to publish any information which could be of use to its competitors.

However, aggregate information that does not distinguish between products is limited to the sponsoring governmental body - Governmental Companies Authority. More general information on bromine and compounds production can be found in trade journals and publications such as that of the U.S. Bureau of Mines.

By making use of the above sources and general information from internal company reports and other informal sources such as interviews with management, it is possible to identify and describe the company's current strategic posture. To this end, the following aspects of growth and development, bromine production and sales will now be briefly reviewed.

### 4.9.2 Bromine Production

Bromine production was started in Israel in the 1930s. However, the first modern plant was erected in the 1950s with a production capacity of 16000 tpa. Bromine is not extracted directly from the Dead Sea, but from an effluent brine generated from potash production by another state owned company. This brine is the richest known source of bromine, as it contains 12g/L of bromide ion.

### 4.9.2.1 Production Costs

The manufacturing cost structure of DSB is regarded as confidential information and direct reliable data are not available. Thus, analysts estimating these costs for DSB have had to rely on a set of limiting assumptions. Comparative costs are illustrated in the following comparison between bromine producers:

Table 8: Bromine Manufacturing Costs (new facility)

(In US cents per pound of bromine)

| | DSB | Arkansas | Michigan | Sea Water |
|---|---|---|---|---|
| Brine Cost (1) | 7.0¢ | 4.5¢ | 5.5¢ | 1.0¢ |
| Chlorine | 7.0 | 3.0 | 3.0 | 6.0 |
| Capital-related expenses (2) | 12.0 | 6.0 | 12.0 | 20.0 |
| Energy | 11.0 | 4.5 | 5.5 | 6.0 |
| Labour | 3.0 | 2.0 | 2.0 | 3.0 |
| | 40.0¢(3) | 20.0¢ | 28.0¢ | 36.0¢ |

Reproduced from: Bromine, Goldman Sachs Research, New York, 1976, p.9

Assumptions[33]

(1) Brine costs exclude energy but include capitalized brine investment.

(2) Capital-related expenses comprise: depreciation, 10% straight line; maintenance, 10% of capitalized investment; taxes and insurance, 2% of capitalized investment.

(3) In DSB energy and capital investment costs assume absence of cheap cooling water and raw brine from the Dead Sea. Under current operations the raw material is bitterns recovered from an adjacent potash evaporation facility.

The above assumptions particularly as they affect the DSB estimate are open to criticism. For example, assumption (3) assumes utilization of raw brine from the Dead Sea whereas in fact, as the report itself points out, the raw material is effluent brine from potash production. The difference between the two alternatives is most significant as Dead Sea brine contains 5g/L bromide ion whereas the effluent brine contains 12g/L. The report recognizes that energy requirements are inversely related to bromide concentration (i.e. the higher the concentration, the lower the per ton energy costs). Yet, in spite of this, the report arrives at a figure of 11¢/lb for Dead Sea production versus 6¢/lb for sea water production. This is entirely an unlikely result, as will be shown later.

As far as the cost of chlorine is concerned, the report does not state its assumption, but 7¢/lb is high for the following reason. Prior to 1975, DSB purchased chlorine from another company and shipped it a distance of over 400 km - resulting in costly chlorine. But since 1976, when the Goldman Sachs report was published, chlorine has been produced on site. The figure of 7¢/lb is high presumably, since it was based on the previous policy of bringing in chlorine from outside.

Following the above criticisms, it is not surprising that the manufacturing cost of DSB's bromine, which should, because of the high concentration, be relatively low, is overstated when compared with that of sea water plants which rely on the most dilute source (and hence the most expensive) of bromine. Further, the high cost estimate is not consistent with the rapid development and growth of sales of DSB. This rapid development is summarised in a recent article as follows:[34]

> "In 1971 DSB ranked as fifth largest producer in the world, selling 12000 tpa. Ahead were the U.S., Britain, France and the Soviet Union. World production rose during the rest of the decade (the 1970s) by 80,000 tonnes, or over 30 per cent. Nearly all the increase was accounted for by two countries: Israel (plus 38,000 tonnes) and the US (plus 32,000 tonnes). Israel is now the world's second largest producer and its top exporter - given that 96 per cent of her bromine output is sold abroad, in elemental or compounded form."

Clearly a better cost estimate that is compatible with the above is required. As stated earlier, this cannot be based on directly obtained data, but instead more realistic alternative assumptions can be made.

## An Alternative Cost Estimation

(a) In DSB capital-related expenses include, brine investment, chlorine plant and bromine plant.

A DSB internal report in 1977 states that the investment for a capacity of 40000 tpa bromine plant plus an appropriate on site chlorine plant is about \$26,000,000. Using Goldman Sachs' formula in assumption (2) above, we get:

$$\frac{26,000,000\ (0.1 + 0.1 + 0.02)}{40,000} = \frac{572}{4} = \$143/\text{tonne or } \frac{6.5¢/\text{lb}}{1977\ \text{prices}} \text{ at}$$

(b) Energy figures extracted from Appendix B- at 1981 prices

(c) Chlorine energy requirements - Appendix B- at 1981 prices

(d) Labor including chlorine - as in Goldman Sachs' report - at 1976 prices

These can be summarized in the following table:

Table 9: Bromine Manufacturing Costs (New DSB plant)

(In US cents per lb)

| | Dead Sea | Dead Sea 1976 prices (1) |
|---|---|---|
| Brine Costs | 0.0 (a) | 0.0 |
| Energy | 4.5 (b) | 3.0 |
| Chlorine | 3.0 (c) | 2.0 |
| Capital related expenses | 6.5 (a) | 6.0 |
| Labour | 3.0 (d) | 3.0 |
| Total = | 17.0 | 14.0 |

(1) Adjusted (rounded up) according to the average Producer Price Index, published by the U.S. Department of Labour.

To conclude, if the assumptions of Table 9 are realistic, then DSB has a significant cost advantage over its competitors, particularly the ones using sea water. Such a comparative advantage is consistent with the rapid development noted above and the increases in production and capacity (see tables 10 and 11).

### 4.9.2.2 Actual Production and Capacity

Table 10: Israel and World Bromine Production

| Year (000 tonnes) | World (Incl. U.S.) | Israel | Percentage |
|---|---|---|---|
| 1970 | 216 | 12.5 | 5.8 |
| 1972 | 265 | 14.0 | 5.3 |
| 1974 | 293 | 15.7 | 5.4 |
| 1976 | 310 | 20.9 | 6.7 |
| 1978 | 311 | 34.5 | 11.1 |
| 1979 | 347 | 49.9 | 14.4 |
| 1980 | 289 | 44.1 | 15.3 |

Sources: U.S. Bureau of Mines Publications (from reference 12).

Thus the table shows that within a decade (1970 - 1979) Israel has quadrupled its production in absolute terms and more than doubled its market share.

Table 11: Israel's Actual and Planned Bromine Production Capacity

| Year | 1979 | 1980 | 1981 | 1982 | 1983 | 1985(1) |
|---|---|---|---|---|---|---|
| Capacity (000 tonnes) | 50 | 56 | 62 | 66 | 70 | 100 |

Sources: Internal DSB Report 1981

(1) Bromine, U.S. Bureau of Mines; U.S. Government Printing Office 1981.

This table shows plans to double capacity within a period of six years. Total world capacity will be according to Table 7, about 488000 tpa and Israel's share of total world capacity will be therefore nearly 21% as compared with ca. 15% in Table 10.

The constant improvement in the competitive position of DSB in the international bromine market, supports the conclusion of section 4.9.2.1.

### 4.9.3 Sales of Bromine and Compounds

DSB produces and exports both bromine and speciality bromine compounds, but bromine is seen as the major product and sales of its compounds is expressed in tonnes of bromine content.

Table 12: Export of Bromine and Compounds (in tonnes of bromine content)

| Product/Year | 1975 | 1976 | 1977 | 1978e |
|---|---|---|---|---|
| Bromine | 6,200 | 9,100 | 12,500 | 14,400 |
| Ethylene dibromide | 3,000 | 2,600 | 6,900 | 9,530 |
| Methyl bromide | 3,900 | 4,400 | 5,600 | 5,400 |
| Bromides (inorganic) | 1,800 | 2,500 | 2,500 | 2,600 |
| Bromides (organic) | 600 | 740 | 1,200 | 400 |
| Tetrabromobisphenol A | 200 | 840 | 1,300 | 1,660 |
| Local Consumption | 650 | 720 | 850 | 510 |
| Total bromine production | 16,350 | 20,900 | 30,850 | 34,500 |

Source: Internal DSB Report 1979

The figures in the following table comprise sales of both bromine and its compounds in Europe.

Table 13: Sales of Bromine and Compounds

| Year | Sales (FOB) (Millions) ($) | Pretax Income (Millions) ($) | Return on Sale Per Cent |
|---|---|---|---|
| 1978 | 31 | 6.0 | 19.4 |
| 1979 | 44 | 8.5 | 19.3 |
| 1980 | 48 | 8.0 | 16.7 |
| 1981 | 57 | 8.0 | 14.0 |
| 1982 | 70 | 10.0 | 14.3 |

Source: Administrative report to the State of Israel 1982.

Aggregated sales figures as shown above give no indication of elemental bromine contribution to total sales. But given total tonnes of bromine sold in Europe, together with knowledge of competitive landed prices in Europe together with their transportation costs, it is possible to estimate the FOB price per tonne at point of export (Table 14).

Table 14: Elemental Bromine Sales

| Year | Competitive Landed Price in Europe (US $/tonne) | Transportation to Europe (US $/tonne ) | FOB Price Point of Export (US $/tonne) | Sales (000 tonnes) | Sales (Mill ( |
|---|---|---|---|---|---|
| 1981 | 775(1) | 141(1) | 634(3) | 32(2) | 20.3( |
| 1982e | 675 | 132 | 543(3) | 40 | 21.7 |

(1) Average figures obtained from DSB's Marketing Department.

(2) A 1981 report to the Board

(3) Calculated

It remains to estimate the FOB cost at port of export. Taking the competitive landed price per tonne bromine in the U.S.[35] as between \$617 - \$650, and given transportation cost[36] of \$282 results in an FOB price of \$335 - \$368. Using \$650 as a worst case assumption and relying on the fact that in 1981, DSB stopped bromine shipments to the U.S. because the CIF selling price had reached the company's break-even point[37] then the FOB cost at the export port would be:

650 - 282 = US \$368 per tonne bromine.

If this estimate is correct, then the margin for bromine exported to Europe can be calculated by using the FOB selling price from Table 14:

(634 - 368)/634 = 42%

Thus, given the considerable elasticity of demand for bromine, the above large margin can serve as a basis for a strategy of price competition in Europe. The fact that bromine has a considerable elasticity of demand is evident from the following table:

Table 15

| Sales/Year | 1960 | 1965 | 1970 | 1975 | 1978 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|
| (000 tonne) | 79 | 125 | 159 | 185 | 203 | 226 | 172 |
| US \$ (Millions) | 34.8 | 55.0 | 61.3 | 77.0 | 86.7 | 102.5 | 87. |

Based upon U.S. market prices and production figures from: "Chemical Products Synopsis", Mannsville Chemical Products, March 1982.

This table shows that an increase in revenues is directly related to the increase in tonnes sold. Also, as has been shown in section 4.5, bromine is a product with several alternative uses - which is another factor affecting positively its price elasticity of demand.

### 4.9.4 A Concluding Remark

The company relies on its own rich bromine source which gives it a cost advantage over all its competitors, particularly the European ones which rely on sea water as a bromine source (see Tables 6 and 9).

If the assumptions concerning Table 14 and competitive landed price in U.S. are correct, then the large margin, e.g. 42% in 1981 and the considerable elasticity of demand for bromine permit the company to pursue an effective price competition. Table 12, which shows an increase in Israel's production vs. decline in world production, and Table 13, which shows an increase in sales and decline in return on sales, support the view that the company pursues a strategy of price competition.

The company also pursues a strategy of vertical integration. Nearly half of the company's bromine output is processed locally into upgraded bromine compounds (which are easier to handle and to ship than bromine) which are then exported. This trend of increasing integration forward is well reflected in Table 10. This indicates that the company's long-term objective in this context is to process locally all its bromine output and to become an exporter of bromine compounds. It should be noted, however, that it is worthwhile to pursue vertical integration only with bromine compounds which require bromine as a major cost item.

The company expects that these strategies will achieve the growth forecasted in Table 11. Nevertheless, it should be noted that the production potential of the Israel bromine industry is huge.

Conservative estimates in the industry suggest a potential capacity of over 1 million tonnes per year using existing production technology.

However, the maturity of the bromine industry and the risk of phase-out of important bromine outlets (indicated in section4.5), suggest that relying on conventional growth strategies may be inadequate in achieving even the 1985 expanded capacity (Table 11). To reduce this risk, it is necessary to consider less conventional strategies of growth through technological change.

## 4.10 Summary and Conclusions

We have seen that there is a considerable disparity between the huge production potential and the relatively limited consumption pattern of bromine.

Examination of the situation of the Israeli bromine producer reveals a strong desire to attain the beneficial and profitable utilisation of its bromine production potential.

In such a situation, a conventional strategic response would be to pursue portfolio diversification or expansion or a combination of both strategies. However, we have seen from the examination of the literature on corporate strategy in Chapter 2 that these strategies would only be useful for either growth-oriented firms operating in areas of growing demand, or firms not being particularly specialised, that are prepared to move away from any given area of activity through portfolio diversification.

In view of the special circumstances of the Israeli bromine producer, both portfolio diversification and expansion can contribute little to aiding the latter in attaining its production objective as outlined in Chapter 3, section 3.6.6.2.

There is clearly a need for a different approach which seeks to change technological circumstances. It is the thesis of the present study that only strategies relying on technological change can meet the challenge.

The next chapter discusses general problems associated with technological change with special reference to the developmental pattern of basic chemicals. The discussion leads to the technological growth tree presented in Chapter 6, where the usefulness of the tree is demonstrated by pinpointing promising opportunities for bromine.

# CHAPTER 5

# GROWTH THROUGH TECHNOLOGICAL CHANGE

The present chapter is concerned with the process of technological change.

We have seen that conventional corporate strategies tend to accept technology as given leaving the firm to adapt to circumstances as the need arises. While these strategies may be appropriate in areas of growing demand or for non-specialized firms, in the case of a specialized firm especially in an area of declining demand, a different approach to growth is required.

The general case of the chemical industry is discussed in this chapter, while the particular case of bromine is taken up in Chapter 6.

## 5.1 Introduction

The process of technological change consists of the following major phases:

(i) Recognition of need.

(ii) Research, leading to the new idea or invention, usually establishes technical feasibility.[1]

(iii) Development and improvement of the invention in order to make it commercially attractive.

(iv) Diffusion - recognition of the advantages of the innovation and its spreading among users.[2]

The last phase - diffusion - provides necessary feedback to former stages and ultimately determines the realization of a technologically based opportunity.

Therefore, a principal objective of this chapter is to examine the process of diffusion and draw some preliminary conclusions for growth through technological change in the chemical industry.

In order to do this, both the economic and sociological[3] approaches to diffusion are outlined and their relevance to the chemical industry is then discussed. The purpose is to propose a developmental pattern for basic chemicals as a synthesis of the above approaches with attention to the nature of basic chemicals and the chemical industry.

The chapter commences with the economic approach to technological diffusion which has concentrated on relating economic variables to rates of adoption of an innovation. This approach, which attended to diffusion in the industrial environment, has recognized that an invention is often not clearly defined at the outset but evolves throughout the diffusion process.[4] This concept of evolution can lead to the sociological view of business firms as advanced learning systems, thus adding another dimension to their role of economic institutions.[5]

The sociological approach was mainly concerned with the societal phenomena, associated with an introduction and spread of an innovation within a social system.

The chapter concludes with the outline of the developmental pattern of basic chemicals. The latter identifies two principal modes of growth of basic chemicals, the competitive mode and the innovative mode.

## 5.2 The Economic Approach

### 5.2.1 Mansfield Model

This represents the best known diffusion model in the industrial environment.[6] His main interest is in the economic aspects of the diffusion process, and his analysis consists of two groups of factors affecting the rate of diffusion.

(i) Economic characteristics of the innovation.

(ii) Economic characteristics of potential users.

Mansfield also briefly notes the importance of a third factor:

(iii) Learning

The first group of factors is concerned with aspects of the innovation that determine its ultimate or equilibrium level of use.

Mansfield[7] distinguishes between consumer products and industrial products and processes. The ultimate level of use of the former depends on how much of it consumers are willing to purchase at the price it can be profitably produced. Subject to the consumer maximizing his marginal utility, which takes into account individual tastes and subjective consumer preferences. These factors play a key role in the diffusion of a new consumer product.

For a new industrial process, on the other hand, the ultimate level of use depends upon: (a) the extent of its economic advantages over other alternative processes, and (b) on the sensitivity of the demand for the product it produces to any increase in quality, or decline in the price induced by the new innovation.

The mechanism, describing the effect of economic advantages of a new process on its equilibrium level of use, can be explained in terms of Salter's simple model, in a perfectly competitive environment.[8] Thus, it can be said that three determinants affect the economic advantages of a new process: The present and the expected price of the product; the present and the expected prices of production factors, and the quantities of production factors required to make a unit of output. Technical progress directly influences the last determinant, since technology at any given time sets the limiting requirements for labour, equipment and materials which constitute the production capacity and indirectly affects the others too.

Salter's simple model suggests that, if prices of the product and factors of production do not change, the new process permits a lower level of operating costs and capital costs. In these circumstances, the lower costs (or the economic advantages of the innovation) would lead to the accumulation of excess profits. These surplus profits may attract attention and induce further use of the new process. The new plants can cause an expansion of output and (subject to demand[9] conditions) a reduction in prices to a level at which the surplus profits decline until a level of normal profits is reached.

At this point, some of the older plants embodying past technology can still remain in operation providing their net operating costs are below the new level of prices. Replacement will take place only when expected earnings of a modern plant exceed expected earnings of an existing plant by a margin sufficient to repay the initial investment and earn a normal rate of return at required level of risk.

At this new level of prices the industry is said to be in instantaneous equilibrium: no more plants will be constructed at the current price and none of the existing ones will be scrapped or replaced by new plants employing the new process. In these circumstances, the number of the latter that are in operation can be identified as Mansfield's equilibrium level of use of the innovation.[10]

It should be noted that an important criterion for assessing the significance of an economic advantage of an innovation emerges from the simple model. This criterion can be formulated according to the following inequality:

new operating costs + costs of change < old operating costs

Thus, an economic advantage can be measured in this way only in instances where some past experience, serving as a basis for comparison, has been accumulated. The model is therefore most appropriate in cases where the innovation represents a new process for the production of a known product. But it can be criticized for ignoring concomitant risk during the gestation period, inertia and availability of funds, but above all, it ignores the ability of both the supplier and the adopters of the innovation to learn. Mansfield, on the other hand, does acknowledge learning, but his main concern is economic characteristics of the innovation and of the potential user. To these and the effects of learning we now turn.

#### 5.2.1.1 Economic Characteristics of the Innovation

Mansfield has isolated four principal characteristics of an innovation which affect the speed of obtaining its equilibrium level of use:

(i) The magnitude of its economic advantages over the former alternatives.

(ii) The degree of initial uncertainly in using the emerging innovation.

(iii) The degree of commitment in experimenting with the innovation.

(iv) The rate of reduction of the initial uncertainty regarding the performance of the innovation.

Thus (i) may govern the speed of diffusion, since the greater the magnitude of the economic advantage of the innovation, the faster will be the latter's diffusion and the quicker it will obtain its ultimate level of use.

The remaining factors (ii to iv) represent various aspects of risk associated with the use of the innovation. If it is assumed that, on balance, adopters are risk aversive, then the rate of diffusion of an innovation would be inversely related to the level of risk and uncertainty associated with it. In this respect, two requirements are made:

(i) Its economic advantages or expected profitability should be large enough to compensate for risk.

(ii) It should possess risk reducing properties such as observability, trialability and simplicity.

The first requirement simply suggests that the higher the expected profitability in using the innovation, the higher will be the probability of its adoption. Mansfield finds here an economic analogy to the classic psychological laws relating reaction time to the intensity of the stimulus. "The profitability of an investment opportunity acts as a stimulus, the intensity of which seems to govern quite closely a firm's speed of response."[11]

The second requirement suggests that the probability of adoption is related to the risk reducing properties of the innovation. For instance, the possibility of testing the innovation (which is seen by Rogers as the possibility of trying out the innovation on a limited scale), may be alternatively seen as the degree of commitment in experimenting with the innovation. Thus Mansfield argues that for equally profitable innovations, the probability of adoption is smaller for innovations requiring large investments which cannot be tried on a limited scale.[12] This is because firms will be more cautious before committing themselves to large and expensive projects.

### 5.2.1.2 Economic Characteristics of Users

The second group of factors determining the rate of diffusion of an innovation is associated with the economic characteristics of the receiving systems. Mansfield asserts that the probability of adoption of an innovation depends on the specific industry into which the innovation is introduced.[13] This is because industries may differ in their attitudes towards risk and experimentation, in the degree of competition experienced, or their financial health. Thus a given innovation may spread faster in an industry which is more inclined to experiment and take risks, financially healthy and operating in a highly competitive environment.[14] Risk has a central role to play in the required characteristics of potential users:

(i) They must have the ability (or facilities) to cope with risks.

(ii) They must have a favourable attitude towards taking risks.

Mansfield lists four economic characteristics expected to affect a firm's speed of response:

(i) Size of the firm,

(ii) Growth rate of the firm,

(iii) The firm's profit level and profit trend,

(iv) liquidity of the firm,

and argues that, other things being equal, which they are not, only (i) has a significant effect on the firm's speed of response to innovation. He explains this by the better means for accommodating innovations and tackling the risks associated with them, which the larger firms are expected to possess.

As far as the other characteristics are concerned, Mansfield argues that although one would expect them to affect rate of adoption, his empirical studies do not show any significant relationship.[15]

However, the logic of Mansfield's argument is questionable, since each characteristic may have aspects both facilitating and discouraging adoption which may readily offset each other. To take one simplified example: on the one hand, a profitable firm might be expected to adopt a new technique more quickly than its comparable non-profitable rival, simply because its greater cash inflows and better credit ratings make it easier to finance a new investment and to bear the risks involved; and conversely, a high level of profit may make the management believe that what they are doing is best for them and there is no pressure to adopt innovations. Similar lines of argument could be drawn for other characteristics in the (ii) - (iv) range, pointing to the inherent difficulty in determining the net effect of these characteristics on the rate of adoption, and explaining the inconclusiveness of Mansfield's empiric results. However, not only the logic of Mansfield's arguments is questionable, but even the statistical interpretation of Mansfield's work is open to criticism.

For instance, Davies[16] has observed that, for the parameter of size of the firm, Mansfield's equation has been fitted to his collection of data for all innovations and industries without any adjustment of the coefficient of the size parameter. He argues, quite convincingly, that this makes the statistical interpretation of the size parameter particularly hazardous: one cannot be sure that it reflects the inter-firm, rather than interindustry size effects.[17]

### 5.2.1.3 Effects of Learning

As we have seen, the economic characteristics of the innovation and of the potential user, have received considerable attention in the Mansfield model of diffusion. The effects of learning and behavioural factors on the other hand have received less attention.[18] Mansfield only briefly notes that the supplier's learning results in continuous modifications to the innovation which keeps changing throughout the diffusion process:

> "Early versions of an innovation often have serious technological problems, and it takes time to work out these bugs. During the early stages of the diffusion process, the improvements in the new process or product may be almost as important as the new idea itself."[19]

The behavioural factors are discussed in section 5.3, whereas the idea of 'learning by doing' by the manufacturers of the innovation was picked up and elaborated by Davies.

### 5.2.2 The Davies Model

In this model, the degree of learning associated with the innovation becomes the criterion for classifying them. Thus Davies distinguished simple innovations (termed group A) for which most of the post invention improvement will be effected relatively quickly, from the more complex and expensive innovations (termed group B), for which learning by doing may be more sustained and eventually more substantial. This classification gave rise to Davies' suggestion that the shape of the diffusion growth curve (describing the growth in the cumulative number of adopters of the innovation) should differ between these two broad groups of innovations. Group B should show symmetrical cumulative normal S shaped diffusion, in contrast to the positively skewed cumulative lognormal diffusion curve proposed for the group A innovations.

The value of Davies' approach is not so much in shaping the curves, as similar shapes have been postulated by earlier studies, but rather in relating the shapes to the different technological characteristics of group A and group B innovations.[20] This separation enabled the study of interfirm differences in the speed of diffusion of basically similar innovations to be examined free of the influence of the innovation's characteristics on the rate of diffusion. By doing so, Davies' model has acquired better explanatory power than earlier works possess. Davies has suggested, for instance, that in most industries almost all firms will eventually use the same major (group B) processes (though different vintages). But, as far as minor innovations (group A) are concerned, even several years after these processes first become available, one can still find many firms which choose not to adopt them. This phenomenon is explained by reference to the two types of learning curves (corresponding to the group A and group B innovations) and the information flows and competitive pressures associated with them. Thus the continuous post invention improvements in the major processes which result in a considerable comparative advantage for an adopter, lead to competitive pressures which make their widespread adoption almost unavoidable.

On the other hand, Davies suggests that the competitive disadvantages of not adopting the minor innovations are perhaps less significant and obscured by other interfirm productivity differences. He points out that if this rationalization is correct, it constitutes an addition to the existing body of knowledge concerning 'learning by doing'.[21] Davies' most valuable contribution is essentially the very distinction he makes between major and minor innovations.

This represents a departure from previous work and by maintaining the minimum number of variables that may change simultaneously, Davies' approach yields more explanatory factors for determining the rate of diffusion than earlier models.[22]

His economic analysis has actually resulted in five such factors.[23] He asserts that diffusion should be faster: (a) the more profitable the innovation, (b) the fewer firms there are in the adopting industry (and because diffusion is a proportional concept, this is not a trivial finding), (c) the smaller the size inequalities between firms, (d) the greater the labour intensity (defined as the share of value added (not output) allocated to wages and salaries at the mid-point of the diffusion period) of the adopting industry, (e) the faster the rate of growth of the adopting industry.

The first finding that diffusion speed appears to be more rapid, the more profitable the innovation for potential adopters, is in agreement with Mansfield's similar result and interpretation which have already been mentioned. The second statement that the fewer firms there are in an industry, the more rapid will become the diffusion of the innovation, is explained by the proposition that information exchange and contacts with innovation suppliers will be more frequent and more effective in industries with a small number of firms. The next contention that diffusion will be slower, the greater is the variance in size between firms, follows logically from Mansfield's finding that firm size has an important effect on the firm's speed of response to an innovation.[24] Observing that firm size inequalities is directly related - and the number of firms is inversely related - to industrial concentration, Davies appears to be right in concluding that it is not possible to say, directly, whether increases in concentration increase or decrease diffusion speed.[25] This is presumably the reason he tackles separately the two components of industrial concentration.

The fourth finding that labour intensive industries are quicker to adopt new innovations, appears strange to Davies. He argues that this may be explained if one accepts Salter's proposition that the variance in age of existing capital stock will be lower in labour intensive industries, and thus so too will be the variance in the profitability of adopting the innovations.[26] It should be noted however that Davies' definition of labour intensity (see (d) above) does not distinguish between low wages and salaries allocated to a large number of unskilled employees and high wages and salaries paid to a relatively small number of highly qualified employees ceteris paribus. Thus, finding (d) may not appear so strange for the latter case where one expects such employees to have modern norms and values, which according to Rogers, characterize early adopters of innovations.

### 5.2.3 Interim Conclusion

In summary, it seems that Davies' model represents a considerable improvement over earlier works, notably that of Mansfield, particularly in its better statistical handling of data, and in the development of the idea of learning by doing by the manufacturer to the extent of proposing two diffusion curves corresponding to the type of innovation, instead of a single curve for all innovations as has been practised so far. His approach has eventually resulted in the identification of a number of significant determinants of diffusion rate, thus broadening Mansfield's final list.

In this context it is interesting to note that Davies' model is responsive to the need "to identify the effects of successive improvements on the technological capabilities and limitations of innovations" that was pointed out in a recent literature survey by Gold,[27] who apparently missed out Davies' important contributions in this area.

Gold also expresses doubt whether diffusion curves are best viewed as sequences of moving equilibrium, or as a disequilibrium adjustment to a given long run position.

Metcalfe[28] argues that this is related to the focus of diffusion research on the demand aspects of the process. He suggests incorporating supply aspects by considering the inducements to manufacturers to produce innovations. In his model, all the fundamental parameters of the diffusion process relating the supply of finance, the innovation's technology, the equilibrium demand curve, and the supply conditions of non-capital input are held constant. Thus, it can be shown[29] how the growth potential, as indicated by a sigmoid curve, may be realized because it is profitable to adopt the innovation and to build up the capacity to produce it. In practice Metcalfe does concede that the above mentioned parameters change throughout the diffusion process and produce new growth curves. Only by accident is the outcome likely to be represented by a logistic trend.

From the lists of factors affecting diffusion produced by Davies and Mansfield, Metcalfe's analysis concentrates on the single factor of profitability, although he broadens its scope by incorporating the profit motive of manufacturers of the innovations.

To sum up, authors in this branch of the literature view learning as an important determinant on the rate of diffusion. But their analysis is more concerned with the economic determinants. And the technological factors, such as R & D activities, behind the innovation process receive much less attention. There is, however, a considerable body of knowledge which relate research and development to the innovation process. This is now briefly discussed.

5.2.4 Role of Research and Development

Technological innovations require the efforts of invention, development and continuous improvement before they become an integral part of economic and industrial life.

To an increasing degree, the task of inventing, developing and improving new products and processes, has been institutionalized through the establishment of formal research and development laboratories. This institutionalization of the innovation process suggests an approach in which the rationality of decision-making constitutes the definitive theme. Indeed, Gold[30] provides extensive evidence to suggest that there is a 'synoptic model' of innovation which relies on the following building blocks:

(a) the belief that technological innovation is inherently attractive to corporations, particularly in the context of potential economic rewards.

(b) the belief that technological innovations are planned and controlled by management.

(c) the belief that decision-making is rational with built-in evaluative feedback loops.

(d) the belief that R&D constitutes the most important means of affecting growth and profitability.

This model is criticized by commentators such as Langrish et al[31] and Jewkes et al,[32] on the grounds that the innovation process is a haphazard one and is often conducted by individuals or firms as a digression from normal activities. But this should not invalidate rational planning if, like Scherer,[33] one distinguishes between the various stages of the innovation process. He suggests that the early stages tend to be conceptual and are typically not subject to detailed planning. The more advanced stages, however, must be planned and controlled if they are to succeed. He also argues that the various stages of the innovation process need not be performed by the same person or even organization. This implies technology transfer. Thus Twiss[34] asserts that a good planning system must exploit unexpected discoveries either by internal development or transferring the technology through licensing.

The term technology transfer has been variously applied in the literature on research management to transfer of the results of research from one field to another, from a developed to a less-developed country, and from the laboratory in general into either related or unrelated areas of application. In this context, Hill[35] notes that "the ability to imitate (to adopt and adapt) is nearly as effective as the ability to innovate in terms of maintaining a favourable trade position. The experience of Japan in the postwar period bears this out". This is in apparent conflict with the belief that R&D constitutes the most important means of affecting growth and profitability. But the conflict is more apparent than real, since a successful imitator must be engaged in research activities in order to be able to adopt and adapt innovations of others.[36] Also, Scherer's proposition that various stages in the innovation process can be carried out by different organizations and people, is relevant to the notion of technology transfer.

Thus Dembo[37] applies this idea in an attempt to transfer research results from a government research institute into external application. In pursuing planned approach to technology transfer, he assigns a key role to a new corporate function - technology transfer management. This function is located at the interface between research and marketing, and its members should have a good perception of the internal mechanisms of both fields. Its role should be the planning and direction of the transfer of research results from laboratory to users. The essential ingredients of the process include:

(a) precise definition of the audience/market that will use the results.

(b) transformation of the results into a form matching the needs and character of the potential users.

(c) feed-back and follow-up as necessary.

These ingredients, particularly (c), imply learning as suggested by Mansfield and Davies. On the other hand, technology transfer management is similar in concept to Rogers' and also Zaltman's notions of change agent and planned change (see p. 145).

To sum up, the industrial-economic literature is mainly concerned, on the one hand, with economic measures and their effects on the diffusion process. On the other hand, there is a considerable body of knowledge that attends to the research and development activities in the innovative process. Social factors, however, are not the focus of interest in the economic approach, but they play the central role in the sociological approach to the innovation process. This is now briefly reviewed.

## 5.3 Sociological Approaches to Diffusion

### 5.3.1 Introduction

We have seen that the economic approach as pioneered by Mansfield (and revised and improved by Davies) is fairly narrow because it attempts to express determinants of the rate of diffusion of innovation mainly in financial terms. Clearly, firms and industries are social systems having their own values and norms, hence their reaction to the demand for change posed by the innovation cannot be fully interpreted through economic analysis.

The sociological approach on the other hand, is mainly concerned with the manner in which social systems perceive the overall net benefits of an innovation and not just the economic ones. Its view is that this perception is the crucial factor which determines adoption.

Two complementary hypotheses of the diffusion process can be found in the sociological category:

(i) The traditional hypothesis sees three distinct stages in the process of technological change. The process is initiated by the recognition of a need that gives rise to an invention which may be an idea, a product or a technique. The innovation stage occurs when, and if, the invention is first introduced to a social system. Then, as the new idea, product or technique is recognized as superior to its conventional competitors, further application of the innovation within the social system takes place and it spreads:that is, imitation or diffusion of the innovation occurs. In this conceptual framework as represented by Rogers, the innovation is assumed to be well defined at the outset and its diffusion is seen essentially as a process of communication.[38]

(ii) The more recent model as proposed by Schon, distinguishes between minor innovations whose introduction does not require significant disruption of the entire technological-social system, and major innovations which precipitate system-wide changes.[39] It is recognised that innovations of the first type are likely to undergo a process which is similar to the one described by Rogers. But for the major innovations which are seen to be developing significantly throughout the diffusion process, it is difficult to draw a solid line between innovation (as introduction) and diffusion (as spreading). The refined model, therefore, attempts to incorporate the fluidity of the internal boundaries of the process.

### 5.3.2 The Rogers Model

Rogers' model of diffusion of innovations rests on two basic assumptions:

(a) The innovation is well defined prior to diffusion.

(b) Diffusion is a one direction movement of the innovation from an emitting centre to a receiving audience.

Diffusion is seen essentially as a communication process where a source transmits a message which travels through channels to receivers. The essence of the diffusion process is, therefore, the human interaction by which one person communicates an innovation to others. This provides the audience with the first knowledge about the innovation. The process which takes place from this stage, until the decision point of adoption or rejection of the innovation is termed the innovation-decision process. The proposed model is most suitable in the case of optional decisions, but similar lines can be drawn for collective and authoritative decisions.

The model consists of the following four phases:

(i) Knowledge - Where the individual is exposed to the innovation's existence and gains some understanding of how it functions.

(ii) Persuasion - In which the individual forms an attitude toward the innovation.

(iii) Decision - At this point the individual acts in a way which leads him to choose between adoption or rejection of the innovation.

(iv) Confirmation - Now the individual seeks reinforcement for his decision but may reverse it if unfavourable responses are received.

The first stage commences when the individual is exposed to the innovation. The question is what determines exposure. Hassinger[40] argues that individuals can be rarely exposed to an innovation's messages unless they can perceive the innovation as fulfilling a need and conforming with their current norms and values. This contention which presupposes that need precedes the innovation, is not entirely objectionable. But the opposite could be equally reasonably argued, that is the need may develop as a result of interaction of the innovation with the social system.

It appears, therefore, that if an innovation is to be successful it must meet one of the following conditions: (i) it should satisfy a well-known need or, (ii) it has to be presented together with evidence of its potential usefulness.

At the persuasion stage, the individual develops a general perception of the innovation and forms a tentative attitude towards it. During this stage, the degree of uncertainty associated with the innovation is high, and the individual is unsure about his feelings about it, and seeks approval for his attitude. Rogers' assumption based on psychological theory, is that the attitude formed at this stage is almost perfectly indicative of the decision taken in the next stage.

The decision stage is characterized by the consideration whether or not to test the innovation. This is a crucial point, since experimentation as a risk-reducing means is for most individuals a key requirement preceding adoption. However, Rogers asserts that the decision to adopt or reject is not terminal, but postponed to the next step.

At the confirmation stage, the individual is still unsure of his choice, and seeks approval for the decision he has made. Conflicting environmental responses may cause him to reverse his previous choice. It appears that throughout this stage, the individual seeks to conform with the system's norms in making his final decision.

The above-outlined model serves as a background for referring to what Rogers terms 'antecedents' to the innovation decision. As with Mansfield, these are divided into two categories:

(i) perceived attributes of the innovation

(ii) characteristics of the adopters.

Five attributes can be summarised for the first category:[41]

1. Relative advantage - Perceived superiority of the innovation over the idea it supercedes.
2. Compatability - The degree of conformity of the innovation with existing norms and needs of potential users.
3. Complexity - The degree of difficulty in understanding and using the innovation.

4. Trialability - The possibility of trying out the innovation on a limited scale.
5. Observability - The degree of demonstrability of the innovation's properties.

Some attributes are of particular importance in certain stages of the innovation-decision process. Thus compatability and complexity are crucial at the knowledge stage, trialability has a key role during the decision stage, and relative advantage and observability should be most important at the persuasion stage.

In the second category of the antecedents of the innovation decision, a crucial aspect in determining the rate of the spreading of an innovation is the attitude towards change of potential receivers, which largely depends on the norms of the particular social system. Generally, social systems and individuals may be roughly classified as having two types of norms, traditional and modern. Members of a social system with modern norms have usually a favourable attitude to change, and are ideally characterized as technically advanced, highly educated, readily interacting with the external environment, having the capability of projecting; i.e., of mentally applying the innovation to their present and future situations. Members of a traditional society, on the other hand, lack these characteristics, are much more conservative in nature, less educated and typically resistant to change. Similarly to the differential role of an innovation's attributes during the various phases of the innovation decision process, the relative importance of the adopter's characteristics depends on the specific stage. Thus, readiness to interact with the external environment is important for the knowledge stage, whereas the capacity of projection is crucial for the persuasion stage.

It appears that the rate of adoption is explicable in terms of the particular combination of an innovation's attributes, phases of the innovation-decision process, and characteristics of the adopter. Rogers' classical model is of particular value in explaining diffusion of a well-defined innovation which is not associated with serious re-orientation of norms and attitudes in the receiving system. However, Rogers appears to underestimate the role of a decisive event or crisis in the innovation-decision process. He merely regards the impact of such an event as emphasising an attribute of the innovation, e.g., relative advantage. Moreover, he asserts that the effect is often temporal since "the members of the social system may make up for lost ground as soon as the crisis is past."[42] This view is appropriate as long as one is concerned with the diffusion of innovations within a relatively stable technological-social system of which they are components. But crisis may have an important role if the diffusion process is seen to be a result of the continuous interaction between system members with traditional norms who resist the innovation, and members with modern norms who favour it. Thus, in cases where the conflict cannot be resolved by the ordinary achievement of consensus, a decisive event or crisis may be required for the transfer from the persuasion phase to the decision phase in the decision-innovation process.

### 5.3.3 Schon Model

The conventional models, notably that of Rogers, regard a well-defined product or technique as the unit of diffusion. Diffusion is seen chiefly as a communication process: a source is emitting a signal which is received by an acceptor responding to it. Schon argues that this concept of communication ignores the tendency of a social system to actively resist change. He defines this tendency as 'dynamic conservatism' and asserts that it makes the process of diffusion look more like a battle than merely communication.[43] The process that Schon regards as diffusion departs from the conventional description in the following respects:

(i) The innovation does not necessarily antedate the diffusion process; it dynamically evolves and develops throughout the diffusion process.

(ii) The process does not necessarily consist of a single source fanning out (stimulating) the innovation. Many sources of related and complementary innovations may be involved. Thus diffusion may consist of decentralised control of dissemination of information.

(iii) An innovation has usually to cope with the receiving system's active resistance to change defined as: 'dynamic conservatism'

Schon suggests that these differences should be taken into account in a representation of the process of diffusion. Four principal phases may form a simple repeating pattern which is the essence of the Schon model: I. Old Steady State, II. Crisis, III. Transition State, IV. New Steady State.

I. At any point in time, an individual or an organisation are dynamically conservative in their social, technological and conceptual frameworks. The latter represents the 'system' of prevailing powerful ideas which are the building blocks of the dominant consensus governing the behaviour of a social system.

II. The stimulus for change in that system of powerful ideas is often a crisis, defined as a disruptive event or sequence of events disturbing the old steady state and inducing demand for new prevailing ideas. Crisis plays a crucial role in stirring ideas which already exist at the margin of society in the old steady state, and in moving them closer to the mainstream.

III. Certain functions have a key role in surfacing and diffusing the undercurrent ideas and in forming the transition state:

(i) <u>Communication</u> - means of communication, whether interpersonal networks or mass media, are not neutral channels of broadcasting. They both modify and interpret the message according to their own tastes and preferences.

(ii) <u>Conflict</u> - the idea's progress in the dynamic conservative environment is characterized by the controversy and conflict it excites. Conflict helps to focus attention on the new idea which becomes an issue for public debate through which it gains more power.

(iii) <u>Champions</u> - distribution of innovation cannot be accomplished without devoted carriers or champions of the new idea. These are individuals or organisations, spreading the innovation through the fields of force created by the interplay of commitment and interests.

(iv) <u>Inquiry</u> - described as a political process in which the movement of ideas to power is associated with a struggle for personal or institutional dominance. Ideas are vehicles through which an individual or organisation seeks to gain influence and obtain power.

(v) <u>Legitimisation</u> - full acceptance and further diffusion of the innovation largely depend on legitimisation. In its crudest form, this is simply adoption of the innovation by opinion leaders (as with the Rogers model) in the social system. Subsequently, the innovation's form and meaning clarify and may even become obvious; these characteristics would facilitate further diffusion along the lines specified by the traditional model.

IV. The emergence of a new steady state of the social system follows legitimisation of the innovation. The new idea establishes itself as a constituent of a new consensus and may now become a candidate for replacement by another idea brought about through a new crisis; thus, the process may repeat itself.

Although Schon's model is concerned with social systems in general, its resemblance to the earlier work of Kuhn who studied specifically the social system of science, is worth noting. This will now be briefly discussed.

### 5.3.4 The Kuhn Model

Kuhn describes science growth as an evolutionary process whose successive stages are characterized by an increasingly detailed and refined understanding of nature.[44] In developing his model, Kuhn introduces the important concepts of paradigm, normal research, crisis, extraordinary research and scientific revolution.

Thus, a paradigm is a set of accepted and normally unquestioned scientific propositions together with suitable procedures for applying them and generating all sorts of problems for further research. Normal research is then a paradigm-based research; a type of activity which resembles puzzle-solving. Problems of normal research are seen as puzzles as long as the paradigm guarantees that they have an assured solution and provides rules that limit both the nature of acceptable solutions and the procedures by which they are to be obtained.

Crisis, it follows, is seen as the persistent failure of the puzzles of normal science to come out as they should. Crisis blurs the boundaries of the existing paradigm and loosens the rules guiding normal research.

The resulting type of research is labelled extraordinary research. Generally, a new paradigm emerges during extraordinary research. Scientific revolution is said to have occurred wherever the new paradigm succeeds in replacing the old one and in creating a new tradition of normal research.

Turning back to Schon's model, the analogy of its concepts with those of Kuhn suggests itself. Thus, for example, Schon's system of prevailing ideas in good currency resembles Kuhn's concept of a paradigm. Moreover, Schon's concept of crisis is explicitly developed by reference to the scientific context: "The analogy with scientific inquiry is helpful. The 'crisis' here is a piece of disruptive evidence incompatible with accepted theory which for some reason cannot be ignored."[45] Schon extends the concept to fit a social system in general and sees a 'crisis' as any happening perceived to be incompatible with prevailing ideas in good currency. He is not clear, however, about the issue of the necessity of crisis in promoting new ideas. Although crisis may be considered to have a crucial role in the adoption of major innovation, it may be argued that perception of increased relative advantage of the new over the old is not necessarily the result of a crisis situation. Kuhn, on the other hand, asserts that in the context of science growth, crisis is essential in bringing about paradigm change. This contention can be appreciated by considering the three types of arguments, as outlined by Kuhn, which are important in promoting paradigm change:

(i) Ability of the new paradigm to solve the problems that led the old one to crisis.

(ii) When the new paradigm is unable to solve these problems, it tends to concentrate on other areas of the field. There, it must permit the prediction of phenomena that had been entirely unsuspected under the rules of the old paradigm.

(iii) Subjective considerations based on the appeal to the aesthetic sense of individual scientists.

The first two arguments are associated with the relative advantage of the new over the old. But as Kuhn explains, the critical issue in selecting a paradigm is not so much its ability in solving present problems, but its promise to guide efficiently future research. A choice between promises must necessarily be based on faith. This is why crisis (in shaking the faith in the old one) is so essential.

Schon's model is not only unclear about the indispensibility of crisis, it is also vague about the way in which crisis is born. Kuhn, on the other hand, recognises that observation-theory match, which is an essential part of normal research activity, is in fact a built-in mechanism for uncovering novelties. Thus the precise anticipations that theory provides serve as a standard; any significant deviations from this standard will indicate the existence of which may ultimately result in crisis.

Kuhn asserts that crisis destroys faith in the old paradigm, but is not sufficient to replace it. Another ingredient is required without which faith in the new paradigm cannot be built. Kuhn suggests that this ingredient is usually subjective and can be expected to appeal to the aesthetic sense of the scientist. Admittedly, only few scientists are capable of abandoning a familiar paradigm on the basis of subjective arguments. But, as Kuhn argues, if the new paradigm is bound to succeed, it is crucial to gain at least a few early supporters who can develop it and demonstrate the advantages of being guided by it. The demonstration will strengthen the persuasive arguments which are based on the relative advantage of the new paradigm. Consequently, more scientists will adopt this new paradigm, will further articulate it and produce further evidence of its usefulness. Gradually, the entire field will adopt the new framework of practice and a new tradition of normal science will follow. These views on the evolving nature of the new paradigm and the role of early supporters are shared by Schon and represent the essential ingredients of his model as outlined in previous pages.

### 5.3.5 Interim Conclusion

Rogers' classic work on the diffusion of innovations is a prominent example of this facet of traditional sociological literature. The literature studies diffusion in terms of the interaction between the attributes of a well defined innovation, and the norms and values of members of a social system who communicate with each other.

In general, recent writings seem to accept this conceptual framework, although they tend to emphasize, or elaborate on various aspects of it. For example, Zaltman and Duncan[46], who are concerned with strategies for planned change, present a diffusion process which resembles the one postulated by Rogers. However, in accordance with their particular interest, they extend Rogers'[47] definition of change agent to include any individual, or group operating to change the status quo in a system. Consequently, the change agent is assigned the key role in their diffusion model.

Sands,[48] who is also interested in directed change-promoting adoption of a new product - relies heavily on Rogers' model in an attempt to apply diffusion theory in marketing new products.

Finally, a recent study by Freeman et. al[49], who briefly surveys the sociological literature on diffusion, confirms that like Rogers, most researchers of the field focus either on the attributes of individuals responding to a well defined innovation, and/or on the social structure which affects adoption behaviour. The main differences are those of emphasis on the various aspects of the general process. Freeman sets out to study the effect of social power distribution within a system on the adoption of a well defined innovation.

As has been mentioned earlier in this chapter, the idea of a well defined innovation implies firm boundaries between innovation (as introduction) and diffusion (as spreading).

Schon, in challenging this distinction, is closer to the economic approach which views the definition of the innovation as undergoing continuous modification long after its introduction. Thus, as with Kuhn's evolutionary approach and the emergence of new paradigms, Schon is concerned with the role of crisis, the evolution of an innovation movement, and the wider systems responses to it.

This study proposes, however, to regard the Rogers and the Schon models as complementary; the former concentrating on relatively minor innovations which are compatible with the receiving systems; the latter, on the other hand, draws attention to the other side of the spectrum, i.e., to major innovations which require substantial changes in the adopting system.

On the whole it may be concluded that to a lesser or greater extent, any innovation entering a new context will be both changed by the shift and will impose change upon the adopter by changing, at least, his behaviour.

## 5.4 Developmental Pattern of Basic Chemicals

### 5.4.1 Introduction

In this section both the economic and the sociological approaches will be discussed in the context of the chemical industry, with the aim of proposing a schema that will account for the growth and development of basic chemicals.

### 5.4.2. The Economic Approach

The economic ajproach to diffusion of innovations has been discussed by Mansfield who was mainly concerned with diffusion of new products and processes in an industrial environment, and this model should be readily applicable to the chemical industry. He was concerned with the notion that an innovation should demonstrate an economic advantage over other alternatives. This could be represented by the following inequality:

costs of change + new total operating costs < old total operating costs.

In this context it should be noted that in the chemical industry the typical "innovating decision" will not necessarily involve the replacement of all equipment but rather will require a change of process. The new process may require however some modifications in equipment or change of part of it.

Perhaps the most valuable contribution of the Mansfield model towards the understanding of the relatively high rate of innovation in the chemical industry is in the crucial role assigned to the reduction of risk associated with using the innovation and consequently in viewing diffusion as a learning process.

As a science-based industry, learning is institutionalized in the chemical industry, in the form of research facilities (see Chapter 2 section on chemical industry) whose elaboration enhances rates of diffusion in the industry. But, as has already been discussed, Davies has pointed out that indiscriminate treatment of minor and major innovations is a notable weakness of Mansfield's model.

Although Davies' model represents an improvement in this respect, and sees degree of learning as a criterion for classifying minor and major innovations, it is still similar to Mansfield's model in its indiscriminate attitude toward labour intensive industries and science-based industries. Needless to say, the two represent different social systems whose members have different norms and values.

### 5.4.3 The Sociological Approach

Rogers' classic sociological model assumes a well-defined one-directional diffusion process contrasting with Mansfield's two-directional movement and evolving process. According to Rogers, once the decision to pursue an innovation has been taken, two factors will determine whether or not the innovation will be adopted. These are (a) the attributes of the innovation and (b) the characteristics of the user.

Chemical innovations are characterized by attributes which allow them to be scaled down for testing in the chemical laboratory and later scaled up for application in the chemical plant. The former is an explicit and efficient tool during the important persuasion and decision stages of the innovation decision process. The chemical industry, being science-based and technically sophisticated, therefore has characteristics corresponding to values assigned by Rogers to a social system with modern norms.

As has already been argued, the apparent conflict between the Rogers and Schon models may be reconciled by assuming that innovations may be classified as in the economic approach, into two categories - minor and major. Unlike the economic approach, the criterion here is not the costs involved, but the degree of incompatibility with existing dominant ideas and/or parts of the social system (resulting in major changes in the behavioural patterna of potential users). For a minor innovation these changes are not substantial, but for a major innovation these changes can be far-reaching. Viewed in this way, the Rogers model may be applicable to innovations of the first category, whereas the Schon model is more appropriate for innovations in the second category.

### 5.4.4 The Schema for Growth of Basic Chemicals

New chemical products and processes can be classified into major and minor innovations, and both Rogers' and Schon's models are complementary in explaining the process of diffusion. Whereas the former explains the diffusion of relatively minor innovations (in Kuhn's terminology - novelties of fact) which on the part of science only require modifications in the dominant paradigm and on the part of society mesh with the existing socio-technological systems, the latter explains diffusion of major innovations (novelties of theory) which on the part of science require a new paradigm and on the part of society may be associated with major reorientations in the socio-technological system.

The diffusion of chemical innovations which fit in with the existing system can be seen as contributing towards the increase in the level of usage of basic chemicals, whereas diffusion of innovations that are associated with system-wide changes, contributes towards increasing the number of end-uses of a basic chemical.

However, none of the models adequately account for the process as to how basic chemicals come to be used as raw materials in a wide range of non-related applications.

The present study suggests that this diversified end-use pattern can be seen as following from the power of basic chemicals to induce property changes in various materials. For example, chlorine is a basic chemical whose role as a component of poly-vinyl-chloride (PVC) is to increase the latter's melting point, thus strengthening its plastic properties. (These are more fully discussed in note 50). Such property changes can result in the invention of new chemical products and/or processes which may be associated either with (i) the establishment of the basic chemical in a particular end-use area or with (ii) system-wide changes which may end up with the emergence of a new end-use area for the basic chemical. Diffusion of both minor and major innovations is involved in the overall process in which a basic chemical gains its ultimate end-use pattern and its level of use.

Figure 10 illustrates that the developmental pattern of use of basic chemicals comprises three principal phases - initiation, propagation and acceptance. Each phase may be characterized by two components of the growth of a particular basic chemical:

(i) the level of use of the chemical in any individual end-use area;

(ii) the number of individual uses.

Three principal phases are proposed although the combination of the two criteria mentioned above may also imply the existence of transitional phases.

Figure 10: The Developmental Pattern of Basic Chemicals

| | | | |
|---|---|---|---|
| Phases | Initiation | Propagation | Widespread Acceptance |
| End-use areas | The chemical is used in a few highly specific industrial applications for a particular property which it possesses. | The chemical is used in a larger number of industries as its broader potential is being recognized. | The chemical is used in all areas of consumption either as an intermediate in production processes or a component of end-products. |
| Annual level of usage | Total level of consumption of the chemical is low on an industrial scale. | Total level of consumption of the chemical is relatively high on an industrial scale. | Total level of consumption of the chemical is very high. |

The discussion below expands on Figure 10.

5.4.4.1 Initiation

An essential prerequisite for this stage is scientific progress in chemistry. The basic chemical is discovered or prepared and its properties in reactions with other substances together with the effects produced in the resultant compounds are investigated.

The knowledge so accumulated provides the necessary background for initiation. Initiation starts when a need in an industry may be met (either through directed search or by chance) by a particular set of effects produced in a molecule by a basic chemical. Recognition of this match stimulates production processes for the chemical and its useful derivatives which marks the phase of initiation.

Research at this stage may be directed at two important aims:

(i) matching needs and effects.

(ii) inventing processes for industrial production of the basic chemical and its desired products.

For example, industrial production of bromine was initiated due to the useful effects for photography it produces in silver bromide solutions.[51] It seems that in stimulating preliminary industrial production, technological imperatives are more important than short-term economic considerations.

This stage, therefore, results in relatively large-scale availability of the basic chemical, which may attract attention from other industries to the material's potential in their context, thus leading to the next phase, propagation.

5.4.4.2 Propagation

This phase is characterized by an appreciation of the material's potential of inducing property changes in various molecules, resulting in an innovation which may diffuse in industries other than the one in which the basic chemical was first used. The eventual adoption of this innovation by such an industry will result in a new end-use area for the basic chemical.

One interesting example is the way in which the health industry has become a new outlet for fluorine. The properties of fluorine compounds which were first used in the refrigeration industry, attracted the attention of the health industry to the property changes which fluorine induces in low alkanes.

The Dyestuff Division of ICI (which was concerned with drugs) was looking for an acceptable anaesthetic which would satisfy the following requirements.[52]

(a) high volatility - necessary requirement if it is to be inhaled.

(b) level of desired potency - the substance should be sufficiently potent to permit the gases administered to contain a concentration of oxygen as high as 80%.

(c) non-toxicity - chemical inertness in the body.

(d) non-inflammability - inflammable anaesthetics such as ether are problematic in the sense that they require expensive and complicated safety measures and preclude the use of the hot wire cautery which the surgeon may need in particular cases.

Low alkanes are fairly volatile, but are inflammable. Substitution of hydrogen by fluorine will lower inflammability without decreasing volatility, since substitution of hydrogen for fluorine has little effect on vapour pressure. The known stability of $CF_3$ and $CF_2$ groups, conferring stability on halogen atoms attached to adjacent carbon atoms was another attribute of the perfluoroalkanes, corresponding to requirement (c). Eventually,halothene was the chosen anaesthetic, and the successful diffusion of this innovation into the health industry has established the latter as an important fluorine outlet.

Research at this stage has a primary role in adapting effects to users' needs. A secondary role is associated with improvements in production processes to enable larger scale availability of the material.

#### 5.4.4.3 Widespread Acceptance

This stage in the developmental pattern of a basic chemical is characterized by the diversity of applications in which the basic chemical participates. These are not restricted to few or related industries, but comprise a whole range of non-related industrial, agricultural and even home uses. To achieve such a widespread acceptance, the potential of the chemical to participate in a wide range of innovations must be recognized and exploited.

Chlorine is a chemical that may be said to have obtained general acceptance. It is used in a wide range of applications, from its biological effects in pesticides and disinfectant to chemical effects as an intermediate in the petrochemical industry. The ultimate consumer areas utilising chlorine's effects are as varied as clothing, jewelry, paints, food and so on.[53] To this one may add chlorine's role in PVC, a polymer which has replaced traditional materials such as wood and metals in many applications, and may be used in creating new areas of social need.[54] This extremely diversified end-use pattern of chlorine, clearly suggests that this industrial chemical has achieved its phase of widespread acceptance.

5.4.4.4 Crisis

Having outlined the principal phases of the developmental pattern of basic chemicals, where the association with industrial innovations has been emphasized, it remains to discuss the role of crisis in this context.

In the Schon model, the key factor in the diffusion of innovation is, by analogy with Kuhn's model for science growth, crisis. Crisis is seen as a decisive event which focuses attention on the innovation and its advantages, and is therefore considered necessary for the perception of the advantages of the new over the old. This view appears acceptable in the Kuhnian world of science, where all scientists must be deeply committed to the dominant paradigm; otherwise, there would be no normal scientific activity. In these circumstances, only the intervention of crisis can weaken commitment to the dominant paradigm; once the validity of the old paradigm is doubted, scientists will be more favourably disposed towards a new one. This explains why crisis is such an essential element in the process of adoption of a new scientific paradigm.

In industry, there is no such deep commitment to the old; hence, as defined by Schon (who followed Kuhn), crisis, in an industrial environment, is not a necessary condition for the perception of the relative advantages of the new over the old. It follows that crisis in an industrial context is not identical to crisis in a scientific context; thus Schon's definition of crisis is unsuitable in this case. This study therefore proposes to define crisis as any event (or series of events) which carries with it an opportunity for the promotion of an industrial innovation.

This definition regards the scientific or technological achievement responsible for the innovation as crisis, in the sense that it provides the opportunity for its first appearance. Similarly, since an industrial innovation evolves throughout its diffusion, subsequent technological achievements which contribute towards elaboration of the innovation are seen as crises, as they provide opportunities for further diffusion of the innovation.

Furthermore, the economic, social and political scenes may also produce decisive events or crises which can provide opportunities for the diffusion of innovation. However, for some events in this category, i.e., war, the common place definition of 'crisis' may coincide with the one proposed in this study. Thus, the second World War, as a major crisis, has provided an opportunity for the diffusion of numerous innovations, e.g., synthetic rubber, penicillin, radar, etc.

## 5.5 Summary and Conclusions

Technological change has long been recognized as a major source for growth opportunities in industry.[55] However, corporate strategy models, like Ansoff's, tend to focus their attention on acquisition strategies rather than on technological change.

Technological change affects social systems and individuals through its outcome, the innovation. The process by which the innovation is spread, is termed diffusion. Two approaches, the economic and the sociological, were presented in this chapter in order to explain the main determinants of the diffusion process and to provide an appropriate background for suggesting a pattern of growth of basic chemicals. It may be concluded that in itself neither the economic nor the sociological approach is adequate in accounting for the phenomena associated with the effects of technological change. Thus, to use a simplified example, economic considerations alone could not explain the development of the polymer industry. This has emerged in the first place from the scientific breakthrough of macromolecular theory.[56] On the other hand, it is obvious that the scientific theory alone, cannot, itself, explain the rise of the polymer industry. Existing industrial infrastructure has to be used, in which one of the dominant forces is economic considerations. These are employed, for instance, in such decisions as the erecting of new plants, substituting of traditional materials by new polymers, etc. Clearly, both aspects deserve attention. Hence they have been considered in this chapter in proposing a developmental pattern of basic chemicals.

The developmental pattern of basic chemicals considers two principal modes of growth, the competitive mode and the innovative mode, which must be taken into account by any basic chemical producer contemplating growth and willing to capitalize on the inherent potential of his chemical. In the competitive mode, growth is sought through expansion, which results in an increase in the level of use of the chemical in its established end-uses. In contrast, the innovative mode is concerned with growth by innovating new end-use categories for the basic chemical thereby increasing its number of outlets.

Having identified the modes of growth of basic chemicals, there remains to develop a general framework, based on these modes, for identifying growth opportunities through technological change.

This is done in the next chapter, where a growth tree framework is formulated whose branches are based on the modes of growth as outlined in the section on developmental pattern of basic chemicals.

# CHAPTER 6

# THE TECHNOLOGICAL GROWTH TREE

## 6.1 Introduction

In the previous chapter we developed a synthesis of the sociological and economic approaches to diffusion of innovations in the chemical industry. The emerging discussion crystallized a developmental pattern of basic chemicals that identified for the latter the competitive and the innovative modes of growth.

The problem remains how to pinpoint the potential technological growth opportunities. Hence a principal objective of this chapter is to formulate a managerial tool - the technological growth tree - that will assist decision making.

A second important objective of this chapter is to demonstrate the usefulness of the approach by applying it to a specific chemical-bromine. It should be emphasized that the object of the exercise is to identify potential opportunities for a bromine producer, but not to make detailed feasibility studies and market research on the operational level which would go beyond the scope of this study.

Instead, the purpose of demonstrating the usefulness of the approach here will be achieved if its application in a specific case can indicate several promising areas of search worth further investigation. It should be noted that for the individual bromine producer, the application of the approach implies the use of both internal and external research and development results in the identified areas.

This chapter concludes that the example of bromine demonstrates that the technological growth tree is a powerful tool which can broaden the range of available opportunities, as opposed to the ones suggested by conventional corporate strategy models.

The chapter commences with the development of the technological growth tree, and this is then applied to bromine against the background information provided in Chapter 4.

## 6.2 The Technological Growth Tree

The developmental pattern of basic chemicals, as outlined in the previous chapter, has identified two principal modes of growth for basic chemicals. The competitive mode which identifies growth with increasing consumption of a chemical in its existing outlets, and the innovative mode which is concerned with growth through the invention of new end-use categories.

The technological growth tree is based upon these two modes of growth.

The main branch in the competitive mode is named technological expansion, whereas that in the innovative mode is labelled technological diversification. Each of these subdivides into relevant strategies and tactics as graphically presented in Figure 11. The various strategies and their corresponding tactics are now briefly reviewed.

### 6.2.1 Technological Expansion

The aim of the following expansion strategies is to increase the consumption of the basic chemical in existing outlets. The strategies labelled price and technical competition are considered separately under this heading, although they are to some extent interrelated.

#### 6.2.1.1 Price Competition

The effectiveness of this tactic largely depends on the price elasticity of demand for the product. The higher the price elasticity, the more effective the strategy. Three important technology based tactics are relevant for large established producers:

(i) exploitation of economies of scale

(ii) improvement in existing production processes

(iii) innovation of new processes.

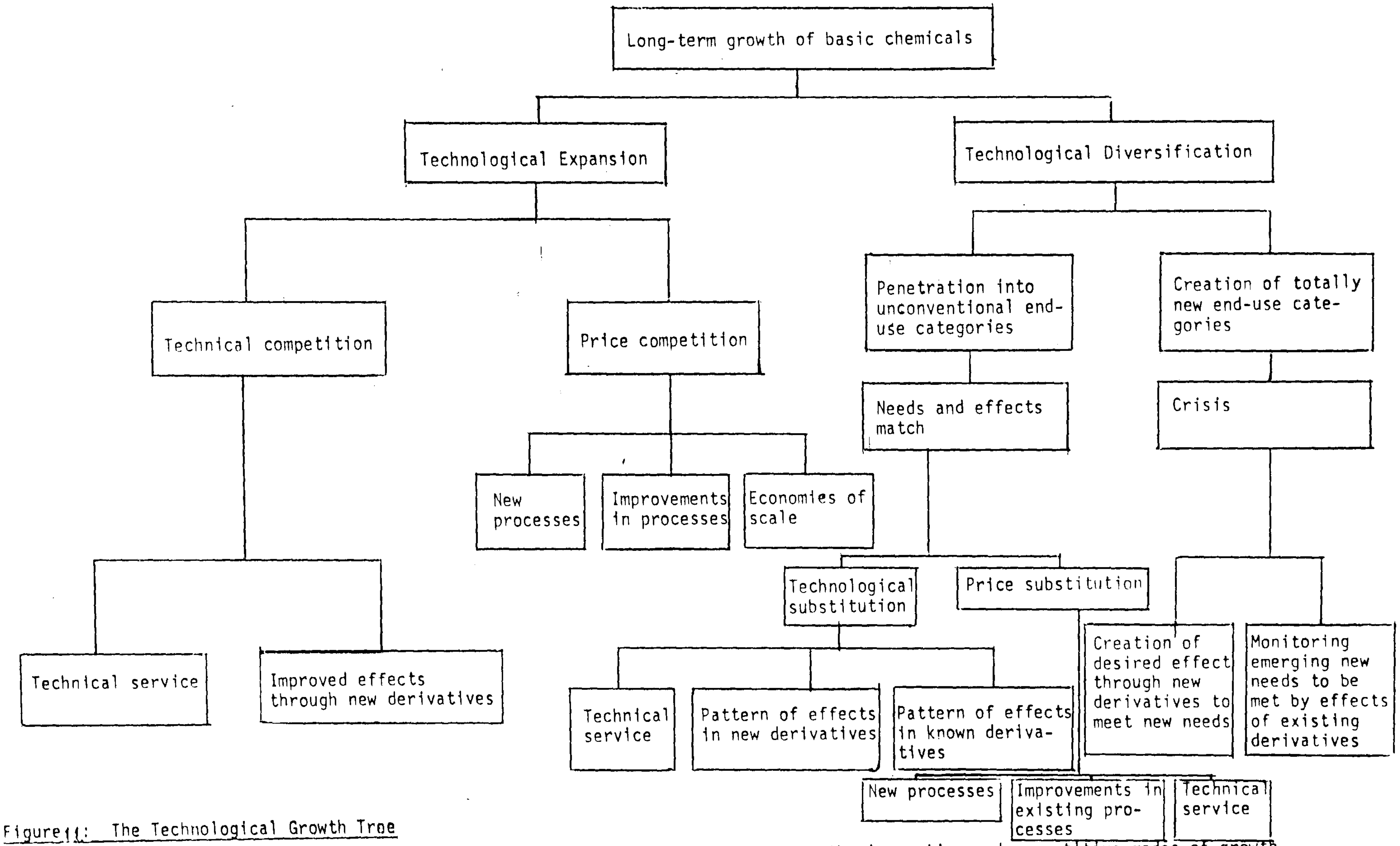



Figure 11: The Technological Growth Tree

The major branches, labelled technological diversification and expansion, represent the innovative and competitive modes of growth respectively.

Exploitation of economies of scale

In simplified terms, economies of scale in the chemical industry are largely governed by the "power rule" known as the Lang factor, relating plant size and costs for a specific product or process. This rule suggests that, all other things being equal, larger capital intensive plants can achieve greater returns than their smaller counterparts.[1]

As was indicated in Chapter 2 (see section on the chemical industry there), the trend for larger plants and concentration of output is noticeable in the chemical industry. However, care should be taken in interpreting concentration of output exclusively in terms of the Lang factor. On one hand, forces such as those aiming at approaching monopolistic and monopsonistic positions in relations with customers and suppliers should also be taken into account in considering the advantages of size. But, on the other hand, it should be emphasized that the risk associated with larger capital intensive plants is considerably higher. This is because such plants require continuous production at high levels of capacity utilization in order to achieve the full benefits of economies of scale. Technological, social or political uncertainties may interrupt production and incur heavier losses than in smaller plants having a smaller proportion of fixed costs. Erection of larger plants to take advantage of economies of scale implies geographical concentration, which, in turn, poses transportation problems resulting from the distribution area of the said product.

On top of these economic considerations, there are also social constraints on economies of scale that should not be overlooked. Geographical concentration of large plants may be associated with greater pollution problems, which are sometimes irreversible, as more of the effluent is localized in a particular region.[2] There are also personnel problems involved in the monotonous work in a large capital intensive chemical plant.

These create social tensions and alienation problems for workers at all levels of employment.[3]

Clearly, a basic chemical producer, particularly a socially responsible one, should be cautious not to arrive at the point where social and economic disincentives outweigh economies of scale related to capital and labour.

Cost reducing innovations in production processes

Two alternative but possibly complementary types of research are relevant here. One is concerned with cost reducing improvements in existing processes, whereas the other type of research is for devising new, more efficient processes for the manufacture of existing products. The following table outlines the main features of the two types of research.

Table 16

| CHARACTERISTIC | TYPE | |
|---|---|---|
| | Research for improvement | Research for new processes |
| Time scale | short (5-20 months) | long (3-10 years) |
| Scientific and technical competence required | No difference between the two types | |
| Managerial competence required | Medium | high |
| Cost of research | small | medium |
| Cost of development | nil to small | high |
| Degree of confidence in commercial application of outcome | very high | medium |
| Chances for technological breakthrough | low | medium |
| Maximum possible return | medium | high |

The characteristics summarised in Table 16 suggest that diffusion of innovations resulting from the two types of research may be interpreted in terms of Mansfield's economic approach to diffusion. The mechanism by which new or improved production techniques contribute toward increased output was described in Salter's model, where no distinction was made between the two types of research.[4] However, both Salter's and Mansfield's criteria appear to favour research on improving existing processes. Firstly, because this type makes lesser demands on the firm's resources, involves less risk and the probability of success is higher. Secondly, the relatively short period required and the high degree of confidence in results yields it more readily to the common economic evaluation methods such as NPV and DCF, which may be used with reasonable certainty to demonstrate the attribute of economic advantage required by Mansfield (see p. 122).

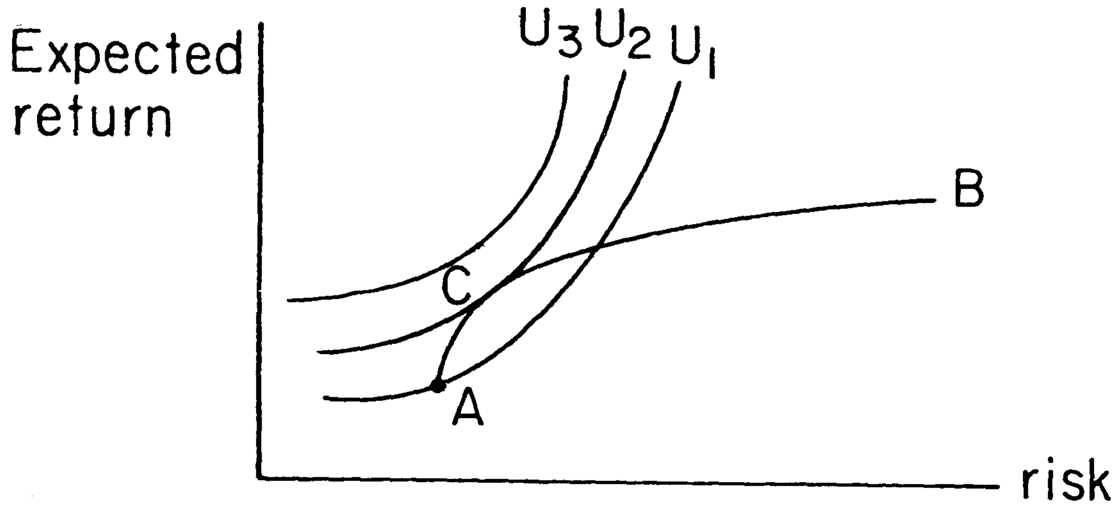
Apparently, research for improving existing production processes for the purpose of more effective price competition, would seem preferable. However, in practice, many firms are also involved with research for finding new processes. At least two factors may account for this: first, there is an incessant quest by scientists for new knowledge; second, there are portfolio considerations in selecting research and development projects. The portfolio approach implies that firms will be influenced in their choice of research and development projects by two considerations:

(i) by the shape of the risk/return trade-off curve,

(ii) by their preferences as represented in utility curves.

If the decision-maker is a risk-aversive his utility curves would rise from left to right, since higher rates of return should compensate for increasing risk. The curves are drawn concave downward on the assumption that additional increments of risks require increasingly larger increments of expected return to compensate the decision-maker.

Figure 12:




In our terms, A represents a portfolio of research projects seeking to improve existing processes. B is a portfolio of research projects for finding new processes. As drawn in the above figure, the hypothetical decision-maker will select portfolio C, where the utility curve $U_2$ is tangent to the risk return trade-off curve. Portfolio C comprises research projects of both types.[5]

6.2.1.2 Technical Competition

Under this tactic, which may be followed where price elasticity of demand is low, the chemical producer may emphasize quality of technical service and/or a new, more effective molecule using the basic chemical in a traditional area of its use.

Technical service

Usually, two major elements dictate a decision to use a chemical:[6]

(i) the product which is of a certain quality and price representing a pattern of effects

(ii) the assistance in efficiently matching the product's effects and the user's needs.

A technical service department is generally concerned with the second element. The exact function of technical service depends on the circumstances in which it operates (see also the discussion on technical service in the context of the tactic of technological substitution). Under the tactic of technical competition, however, a technical service department is associated with close links and frequent interaction with existing outlets. It, therefore, aims at increasing sales of existing derivatives in existing outlets and/or promoting new derivatives in existing outlets.

New derivatives in established areas

This tactic seeks to improve the effects a basic chemical produces for established uses by providing new derivatives in which the useful effects will be more pronounced.

The features of chemical research leading to a new derivative for an established end-use category are similar to those outlined in Table 16 for new processes. In this case, if the resultant new derivative is looked upon as a unit of diffusion which does not require major realignments and changes in the receiving system for adopting the innovation, then the assumptions of Rogers hold, and the new derivative may diffuse along the lines specified in his model (see p.135-139).

6.2.2 Technological Diversification

Under this heading, new applications for the material and its derivatives are examined. New outlets may be added to the present list of a chemical's end-uses in two ways. Firstly, use of the material or its derivatives (new or existing) may be introduced to areas where it has not previously been considered for use. Secondly, these is the possibility of emergence of totally new end-use categories where the chemical or its derivatives can fulfil a useful function.

6.2.2.1 Totally New End-Use Categories

The principal factor which can affect the emergence of totally new market areas for a basic chemical and its derivatives is a descisive event, or sequence of events, termed as crisis. As defined in this study, crisis represents an opportunity in the form of a major scientific or technological breakthrough, or political or social change, affecting both innovation (as introduction) and diffusion (as spreading). Crisis plays an important role in exposing the usefulness of the potential effects the chemical is capable of producing to fulfil unexpected needs. Two tactics are proposed:

(i) Monitoring effects of existing derivatives to meet new needs. An example would be the use of a bromine derivative: ethylene dibromide in fuel additives in the 1920's, when the motor car presented a new need for efficient utilisation of fuel. This new end-use of the existing derivative ethylene dibromide initiated large-scale bromine production.[7]

(ii) Creation of desired effects in new derivatives to meet new needs. This can be exemplified in the case of poly vinyl chloride (PVC). The scientific breakthrough of the macro-molecular theory enabled the development of the polymer industry which is an important outlet for this chlorine derivative (PVC).[8] Plastic materials such as PVC were used to fulfill new needs (see p. 150 for the effects that chlorine produces in PVC).

The scientific and technical background of the basic chemicals industry enables it to participate in research areas that may create new needs. Although direct work on peripheral subjects is not in the basic chemical manufacturer's immediate capabilities, an interaction with the potential user emphasising the material's useful effects and supporting research, may indicate important opportunities that should not be overlooked.

6.2.2.2 Penetration into Existing but Non-conventional End-Use Categories

Compared with the creation of totally new end-use categories, matching needs of existing markets to the basic chemical's potential effects appears to require more direct involvement in appropriate research projects on the part of the manufacturer. In the former tactics, both desired effects and needs are difficult to specify. In contrast, the known needs of existing but non-conventional markets could serve as a basis for defining a target toward which efforts could be directed. The interest in established but non-traditional end-uses implies matching more or less known needs and potential effects by substituting existing materials by the basic chemical's derivatives and their effects. Two tactics for penetration into non-traditional uses, i.e., price substitution and technical substitution are outlined. An important component of both is technical service which is subsequently discussed.

Price substitution

The simplest case is where new applications are obvious and their use is discouraged only because production costs are too high. This suggests cost reduction research either into new processes, or improvement in existing processes. These should be similar in nature to projects undertaken under price competition (see p.160). The main difference is that price competition is held between producers of the same chemical, whereas in price substitution the material and derivatives will have to compete with other materials, thus posing more difficult problems of having to face different market structures which may discourage diffusion, in spite of considerable cost reduction.

Under such circumstances, an economic stimulus as suggested by Mansfield may be inadequate, and only a crisis (as defined in this study) could promote diffusion into non-traditional use. An example for such a crisis would be shortages in traditional materials which are followed by price increases and ease the entry of the new material. Even a threat in shortages, either for political or technical reasons, may increase uncertainty associated with using the traditional materials and offset (or compensate to some extent) the risk associated with using the new ones.

Technological substitution

Similar to price substitution, technological substitution involves diffusion of an innovation (which may be a known or a new derivative of the basic chemical) into a non-traditional end-use area. However, technological substitution takes place whenever new uses are not obvious, and at least initially, cost considerations are not the main barriers to entry, although further diffusion may be later facilitated by cost reductions. The main emphasis here would be the technological superiority of the innovation over traditional materials.

It should be noted that diffusion in this context, is frequently initiated by an event (or crisis) which represents an opportunity for the innovation.

Two tactics are considered under the heading of technological substitution. One involves the introduction and spreading of a known derivative of a basic chemical within a new context, whereas the other tactic involves the introduction and spreading of a new derivative. The thought behind the two tactics is essentially the same, as both are associated with innovation (as introduction) and diffusion (as spreading). Research supporting the two tactics should therefore be carried along similar lines.[9]

The first tactic which involves matching pattern of effects of known derivatives to needs in non-traditional areas has the advantage of availability and at least partial acquaintance with the innovation's properties. On the other hand, as it has been pointed out, prejudice against the known derivative may cause difficulties in promoting its use in new markets.[10] It is suggested that proper technical service and support may ease this problem. However, if further expansion of the known derivative is inhibited only by cost considerations, the issue is reduced to a price substitution problem. The introduction of a known bromine derivative (calcium bromide) into a new area of application (the oil industry) can be seen as an example in this context. The technical superiority of calcium bromide over existing drilling fluids, has accounted for its initial diffusion into the oil industry for use in inferior oil wells. Before the energy crisis broke out, such wells were abandoned since conventional drilling fluids could not be used. The crisis has emphasized the need to utilise the inferior wells, a need which presented an opportunity for calcium bromide to make its entrance into the oil industry. It appears that further diffusion at this stage will be enhanced through considerable price reduction.

The second tactic, which involves matching effects of new derivatives to needs, is understandably more difficult because the effects are yet to be studied. The emphasis therefore is on the expected property changes which the basic chemical is supposed to bring about in a new derivative. An example of this would be introduction of bromine into halofluorohydracarbons (freons) which are used as propellants. Recently, environmentalists have been warning that existing propellants, which easily reach the stratosphere, are destroying the protective ozone layer, thus enabling harmful radiation to reach the earth. Introduction of bromine into a halofluorohydracarbon is expected to result in a new propellant which may not reach the stratosphere so easily and the consequent harmful effect may be reduced. Needless to say, the anticipations mentioned in the example above must be supported by experimental evidence before further research is commissioned.

Technical service

Technical service and its role in the context of technical competition has already been discussed (see p. 165). Here, under both the tactics of price substitution and technological substitution, a department of technical service is seen to function mainly as a change agent. This is because the two tactics, as previously discussed, imply the addition of new outlets through diffusion of innovations stemming from the basic chemical in question. The models for diffusion of innovation assign a key role to communication (Rogers) and learning (Mansfield and Schon). It is suggested that both communication and learning are components of the function of a change agent as undertaken by the technical service department. Thus it communicates the innovation to an audience in non-traditional end-use areas, where it offers technical support for the appropriate utilisation of the innovation, a process which involves learning. It should be noted, however, that there is producer, as well as user learning, since the former has to remove deficiencies from early versions of the innovation, adapt it to user's needs, and the latter has to learn to use it effectively. The technical service department, therefore, provides feedback for producer's learning and can instruct user on the appropriate utilisation. Consequently, an innovation which enters a new context is both changed by the shift and will impose change upon the new context, the most apparent way being through changing the behaviour of users. A related function of technical service, which has been mentioned in literature, is its role as a source of ideas for target research and its part in the evaluation and screening of new products.[11] Thus, at least in principle, a technical service department may induce research aimed at new outlets on one hand, and promote diffusion of the resulting innovations on the other hand.

## 6.3 Interim Conclusion

The technological growth tree as presented in this chapter is based on the two modes of growth as identified in the developmental pattern of basic chemicals in the previous chapter. These are the competitive and the innovative modes of growth, both constitute the major branches of the technological growth tree.

The method outlines a wide range of development opportunities for basic chemicals. The approach is therefore product development-oriented, as it takes into account the potential diversity of end-uses of basic chemicals. Thus, it seeks to strengthen the position of the basic chemical producer both by improving his standing in traditional end-uses of his material and by innovating new ones. In doing so, technology is not seen as given but rather as a subject for change according to the need to change the greater environment and/or to respond to changes in it. This is in contrast to conventional corporate strategy models which accept technology as given and attempt to strengthen the firm's position by pursuing acquisition strategies.

In the following section the usefulness of the approach will be illustrated in its application to bromine, against the background information provided in Chapter 4.

## 6.4 Application of the Technological Growth Tree to Bromine

In Chapter 4, the bromine industry was characterized by uncertain demand on the one hand and rising production costs (due to energy costs) on the other hand. Against this background, the 'unrealistic' production objective of the Israeli bromine producer was recognised.

The competitive strategies proposed by conventional corporate strategy models, which similarly to the competitive branch of the technological growth tree, rely on intentional standards, were found to be of limited usefulness in the attempt to obtain the production objective of the Israeli bromine producer. The common reliance on intentional standards suggests that similarly to competitive acquisition strategies, the competitive branch of the technological growth tree may be of limited use to the Israeli bromine producer. But still, it can have at least one important qualitative contribution. This is because some tactics in the competitive branch of the growth tree have parallels in the innovative branch. Thus, technological and other skills developed in the former can become a basis for the accumulation of knowledge to be used in the latter.

Nevertheless, as has already been concluded in Chapter 4, the goal of breaching the gap between the huge production potential of bromine and its relatively low demand cannot be achieved in the competitive mode of growth, we should consider the innovative mode of growth as the more viable alternative. We turn now to the main branch of the innovative mode, technological diversification.

## 6.5 Technological Diversification of Bromine

Technological diversification seeks to assist a chemical producer willing to capitalize on the inherent potential of the raw material. It therefore attempts to change the circumstances facing the producer by increasing the number of markets or end-uses for his chemical. In general, this strategy is most demanding as it requires a departure from past patterns of development, and innovation of new areas of application for the basic chemical and its derivatives. This strategy, as illustrated in figure 11, can be applied to bromine.

Two principal tactics need to be considered:

(1) creation of new end-use areas
(2) penetration into existing but unconventional market areas.

### 6.5.1 Creation of New End-Use Areas

(i) monitoring emerging new needs to be met by bromine compounds
(ii) inventing new bromine derivatives, thereby creating new market outlets.

For example, tactic (i) may be illustrated by the introduction of ethylene dibromide (as a fuel additive) in the 1920's and could have been applied to the transport industry. In the years after the first World War, the automobile industry had entered a relatively advanced development stage; motor cars became more numerous and their engines more powerful. With the increasing compression ratio of the engine's cylinder, 'knocking' appeared, due to premature explosion of the compressed fuel-air mixture. This new need of decreasing the 'knocking' had to be met if better engines and faster cars were to be developed. It was found that tetraethyl lead was both an effective 'antiknock' agent and economic in use. However, there was a serious drawback; lead oxides tended to precipitate in the engine. This problem defined a new need for an additive that would prevent formation of lead oxide deposits. Ethylene dibromide was shown to possess useful effects in matching the new need. Particularly useful is its reaction with lead oxide which results in a volatile product, lead bromide, to be expelled with the exhaust gases.[12] This and other effects matched the new need of the motor car industry and gave rise to increased demand for bromine.

The example shows that conscious application of this approach on the part of bromine producers in engine development would have resulted in a shift in the demand curve of bromine. The major problem, however, of this tactic is how to identify an emerging new need.

But the great success of the above example shows that in spite of the difficulties associated with monitoring technological change in other areas, basic chemical producers willing to increase the demand for their product must employ this tactic.

The second tactic of inventing new bromine derivatives to meet new needs is much more difficult to follow as a comprehensive theory for relating desired effects to molecular structure and composition would be required. However, at the present stage of scientific development, such a theory is not even available. As opposed to comprehensive theory, there are only instances where a specific theory, relating effects to structure and composition of a particular molecule, exists. Historically, it has often happened that a specific theory has followed empirical knowledge. The famous example in this context is the application of a bromine compound, silver bromide, in photography. Thus, silver bromide was used in photography since 1840, whereas the first satisfactory theory in this subject was introduced a century later, in 1938.[13]

From the above it is clear that monitoring emerging new needs, tactic (i), would require well-coordinated research efforts between end-users and manufacturers.

Given the current state of scientific development, the usefulness of tactic (ii) is dependent on a scientific breakthrough being made in developing a comprehensive theory of molecular structure.

### 6.5.2 Penetration into Existing but Unconventional Market Areas

Compared with the creation of totally new end-use categories, matching needs of non-conventional markets to the useful effects of bromine derivatives appears to require more direct involvement in appropriate research projects on the part of the bromine producer. The interest in established but non-traditional end-uses implies matching known needs with potentially useful effects of bromine derivatives by substituting existing materials in current use. Candidates for substitution could be pinpointed by comparing their effects with those of bromine.

The chemical properties of bromine such as fire retardation and oxidizing power stem from its place between chlorine and iodine in the halogen family. Bromine reacts with organic compounds similarly to chlorine but the C-Br bond is weaker than the C-Cl bond. Bromine's atomic radius is larger than that of chlorine, hence its steric effects particularly in aromatic substitution reactions are likely to be more significant.

An important physical property of bromine is its high specific gravity, (see also Chapter 4, p.85 ). And this property is conferred on bromine compounds which can be used in various applications, e.g. calcium bromide in oil well drilling (see p.177).

These and other properties of bromine are used for introducing property changes into various molecules to yield useful effects such as chemical or biological activity, fire retarding and extinguishing ability or high density in the resultant bromine compounds. Existing outlets for bromine derivatives utilise these effects. Thus the chemical activity of ethylene dibromide to react with lead oxide is used in fuel additives; biological activity is used in agrochemicals, fire retardation in flame retardants, and high density in the outlet of calcium bromide solution as a dense fluid product for use as oil well packs and completion fluids (see Chapter 4, p. 96). The last outlet was only recently introduced, after 1973, which indicates that the effect of high specific gravity which bromine produces in derivatives was under-utilised until then and its full potential is still to be realised. This partial coverage suggests that it is likely that some other properties of bromine such as resemblance to chlorine, the relatively weak C-Br bond and steric effects in aromatic substitution are still under-exploited as potential sources for producing desirable effects to match the needs of existing non-traditional markets by substituting conventional materials. Hence the tactics of penetration into non-traditional areas will seek to exploit bromine's properties.

The technological growth tree sugggests two principal tactics for entering non-traditional markets: (a) technological substitution and (b) price substitution of traditional materials by bromine derivatives.

(a) Technological substitution

The underlying assumption in following the tactic of technical substitution is that straightforward cost considerations are not the main barriers to innovation (as introduction), but diffusion (as spreading) (see p. 134) may be later enhanced by cost reduction. Thus the technological superiority of the new entrant over traditional materials is the focus of attention. These points may be illustrated by referring to an example of a successful technological substitution using a known (see Figure 11 and p. 169) bromine derivative, calcium bromide, in a new area of application - oil well drilling. Traditional drilling fluids are various muds of high specific gravity, but their rough texture often causes technical problems in drilling. Before the 1973 oil crisis, problematic wells were not exploited. But the crisis exposed the need for using inferior wells which could not be utilised with traditional rough drilling fluids. Only a clear solution of high specific gravity could solve the problem. Although the details of introducing calcium bromide were not published, it is reasonable to assume that attention of bromine producers to the hitherto under-exploited property of high specific gravity of bromine has led them to examine soluble bromine compounds (for getting clear solutions), among them calcium bromide which has been shown to provide clear solutions of high specific gravity, suitable to serve as drilling fluids even for inferior oil wells.

The relevant reference standard for comparison in this case is not the cost of the established materials, as these are technically inappropriate for this specific application, but the opportunity costs of not utilising those inferior oil wells.

These opportunity costs which became significant since the recent energy crisis, provide the stimulus (in the form of expected profitability) for using calcium bromide solutions in oil wells which otherwise would not have been exploited.

In terms of the diffusion models outlined in Chapter 5, the energy crisis made possible the introduction of calcium bromide into the oil industry by providing the opportunity of effectively demonstrating the latter's technical superiority over traditional materials. At this initial stage, technological imperatives were much more important than comparing costs of the innovation and the existing materials. However, diffusion (as spreading) of calcium bromide requires a reduction of production costs which is a necessary condition for attracting a wider audience. This phase corresponds to the tactic of price substitution which will be discussed later (p. 184). The under-utilized properties of bromine: (i) high specific gravity, (ii) resemblance to chlorine, but having a weaker C-Br chemical bond, and producing greater steric effects resulting in more stereospecifity in aromatic substitution reaction, are used here to illustrate their potential for inducing property changes in various molecules. In terms of Chapter 5, the resultant inventions, their introduction and spreading are seen to be components of the developmental pattern of bromine.

(i) High specific gravity

It was already argued that the high specific gravity which bromine is capable of producing has led to the successful introduction, triggered off by the energy crisis, of calcium bromide to the oil drilling industry.

The environmental crisis has recently threatened the propellant industry. Existing propellants are reaching the stratosphere and destroying the ozone layer which protects the earth from harmful radiation. Brominated propellants with a high specific gravity will rise into the atmosphere more slowly and because of the relatively weak C-Br bond, they could well decompose and thus would be less likely to reach the stratosphere and damage the protective ozone layer. This need for a relatively heavy propellant and the associated qualities of bromine suggests that the introduction of bromine into halo-fluoro-hydrocarbons, the existing materials used in the propellant industry, could result in a suitable propellant.

Research confirming the usefulness of bromine derivatives in this application is a necessary condition for entering the propellant industry as a non-traditional end-use for bromine.

(ii) Resemblance to chlorine

Both bromine and chlorine belong to the halogen family and display similar chemical properties. However, they differ in degree of reactivity since chlorine is a much stronger oxidizing agent having a stronger electron affinity, thus producing slightly different properties in their organic analogues; e.g., derivatives with stronger C-Cl bond than the corresponding C-Br chemical bond. The differences in size between chlorine and bromine atoms may cause steric hindrances in substitution reactions leading to greater stereospecifity of bromine compounds. The difference in physical properties such as greater specific gravity of bromine is responsible for differences in physical properties of their derivatives. Thus, organic bromine derivatives are less volatile than their chlorine analogues and a bromine inorganic derivative such as calcium bromide has a greater specific density than calcium chloride.

It seems that in the past, substitution of bromine for chlorine was not fully exploited by bromine producers. This was not encouraged because of cost considerations and the well-known (and under present technological circumstances inevitable) Br/Cl unfavourable price ratio. In contrast, the present study suggests using the tactic of technological substitution where, at least initially, cost comparisons with the traditional material are inappropriate (see the example of calcium bromide above). The vastness of the chlorine world market (16 M tpa) together with its diverse end-use pattern, suggest that it is a promising search area for opportunities for technological substitution.

(1) Substition of bromine for chlorine as an intermediate in the petrochemical industry.

The general case

Traditionally, the petrochemical industry was a major outlet for chlorine, consuming approximately 30% of total chlorine production.[14] However, a major problem in this area is the resultant by-product calcium chloride which is a waste material. No practical way was found for re-cycling chlorine from this by-product.

As the technological growth tree suggests, such a problem may become an opportunity which could demonstrate the technological superiority of the new entrant bromine over the established material chlorine. Thus the bromide analogue of the problematic calcium chloride is the valuable calcium bromide discussed previously in this chapter. The practical aspects of this technological substitution require a great deal of research efforts aimed at assessing the attractiveness of the substitution, e.g., the concentration of the resultant calcium bromide is an important factor since if it is too low, substantial costs may be required to increase it, and question bromine's advantage over chlorine.

Specific examples:

(i) Brominated intermediates for aromatic substitutions

As was mentioned above, the difference in the effects that bromine and chlorine produce in their derivatives could become a source for technological substitution. Two bromine properties are particularly significant in this context: (a) the relatively weak C-Br chemical bond, and (b) greater steric effects resulting in greater stereospecifity.

The second property is fairly well known. Thus it has been established that under comparable conditions, chlorination of chlorobenzene would yield 55% of the desired isomer para dichlorobenzene; bromination of bromobenzene leads to 85% of the desired paradibromo.[15]

The other under-utilised property, the relatively weak C-Br chemical bond, seems to account for the greater C-Br reactivity toward carbon dioxide which has recently been discovered.[16] A combination of both effects, stereospecifity and C-Br reactivity toward carbon dioxide may indicate a promising possibility worth further investigation for a new process for terephthalic acid. In this process, as was stated above in the general case, the bromine used for obtaining the desired petrochemical product could be recovered in the form of calcium bromide.

(ii) Petrochemical catalysts production

An important chlorine derivative, aluminium chloride, is a widely used catalyst in chemistry and petrochemistry; it is the raw material for aluminium alkyls, basis of catalysts for modern mass polymers. The bromine analogue, aluminium bromide is much more soluble than aluminium chloride in most organic reagents and solvents. This may imply higher reaction rates and simpler handling procedures.

Although aluminium chloride is cheaper and a more widely known material, the superior technical qualities are potentially capable of reducing overall costs associated with using the traditional material. Again, research efforts directed to demonstrate the advantages of using aluminium bromide are a preliminary condition for a successful technological substitution of aluminium chloride.

(2) Substitution of bromine for chlorine as an inorganic intermediate

An example of specific advantage of bromine over chlorine in this area is its high selectivity in iron/titanium attack.[17] It can therefore be used in ilmenite enrichment to synthetic rutile.

(3) Substitution of chlorinated pesticides

This is an intermediate case for technological substitution of established materials in non-traditional uses, because the agrochemicals field is not a new area for bromine derivatives. However, the pesticides market is dominated by chlorine derivatives, particularly DDT of which millions of tonnes have been produced. It is currently being phased out because of its persistence in the environment and the hazards it poses due to the strong C-Cl bond. This makes DDT very stable and non-biodegradable, a property which causes it to accumulate in living tissues to risky levels. As the technological growth tree (p.169) suggests, environmental awareness may become the driving force and provide an opportunity for technological substitution. It may be recalled from earlier in this section that an under-utilised property of bromine organic derivatives is the relatively weak C-Br bond as compared with the very stable and therefore problematic C-Cl bond. Therefore a bromine analogue of DDT containing weaker C-Br bonds which has been prepared and reported to be less active,[18] may be less persistent in the environment than the chlorinated DDT and may become a successful substitute at least from an environmental point of view.

As technological substitution implies, the examples outlined above and perhaps many other could be found, are based on at least potential technical advantage over traditional materials rather than simple costs comparisons. In most cases, the potential advantage has to be realised through technological innovation by the bromine producer, based on very intensive research and development efforts. In directing research efforts toward technological substitution, attention should be paid to costs of change for the potential users. In some cases, e.g., calcium bromide substituting conventional drilling fluids, practically no costs of change were involved. The traditional materials are technically inappropriate for the specific application for which calcium bromide is used. However, the nature of the specific opportunity for a suggested technological substitution, may affect the extent of costs of change that would be tolerated by the potential user. Thus, if environmental problems provide the said opportunity, bromine producers willing to pursue technological substitution must see to it that at least two conditions are satisfied:

(i) Research must produce decisive evidence about bromine's environmental advantages. Great care should be taken in innovating such compounds that would not pose new environmental hazards.

(ii) Costs of change should be within the limits of society's will and ability to pay for a clean environment.

Price substitution

As the technological growth tree (p.168) suggests, the simplest case of price substitution is where new applications are obvious and their use is discouraged only by cost considerations. Such a case is the use of calcium bromide as oil well drilling fluid, where successful technological substitution for the conventional rough materials has taken place. Calcium bromide is used only for so called inferior oil wells (where the traditional materials are inappropriate) but is not used elsewhere because it is relatively expensive in a situation where cheaper substitutes are available.

Since bromine is a major cost item in the production of calcium bromine, R&D into cheaper manufacturing processes for bromine is required. Thus, if more economical bromine can be produced, this is likely to result in other cheaper end products and hence the growth of the bromine industry.

Other obvious applications of bromine that are currently discouraged mainly because of cost considerations are found in the traditional chlorine markets such as water sanitation, agrochemicals, bleaching agents, etc., where chlorine is relatively cheaper. Under current technology chlorine serves as a raw material in bromine production and it is not presently possible to sifnificantly reduce the Br/Cl price ratio.

Bromine's competitive capabilities could be improved by employing two alternative research approaches:

(i) innovating non-chlorine oxidation method for a new bromine production process.

(ii) direct use of bromides as brominating agents.

A breakthrough in the aforementioned areas would also lead to a solution of a serious drawback in the production of bromine, namely the resulting production of caustic soda when bromine is manufactured. The associated question of caustic soda production and its relation to the chlorine industry is discussed in Appendix C.

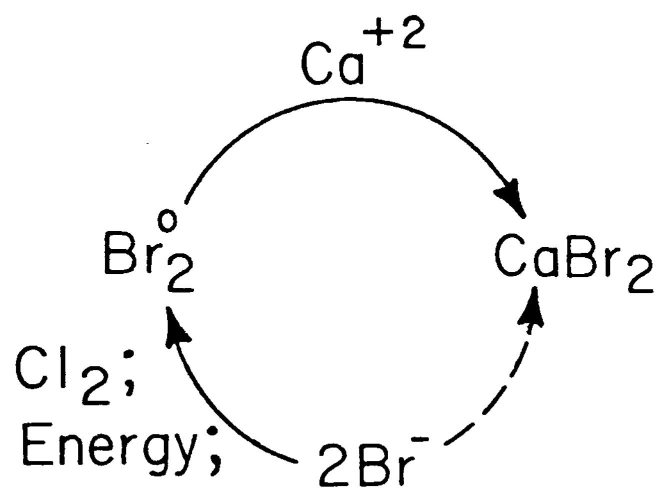
As far as the aforementioned new bromine production processes are concerned, a number of possible alternative non-chlorine processes have been reported in the 1960's including oxidation by manganese dioxide, chlorates, bromates, hypochlorates and electrothermal methods.[19] Although these processes were not commercialised, they indicate the technical feasibility of alternative processes and suggest directions for further research attempting to reduce the Br/Cl price ratio. Eventual success may facilitate price substitution of many chlorine applications.

The second approach of direct bromination represents a departure from the traditional thinking, that bromine chemistry must be based only on elemental bromine, which underlies both existing chlorine based and the suggested non-chlorine bromine production processes.

Traditional thinking and the unconventional approach of direct bromination can be both represented diagramatically for the production cycle of calcium bromide (see Figure 13).

Success in producing calcium bromide directly from the bromides present in the brines may lead to substantial production costs reduction

Figure 13: Production cycle for calcium bromide




The heavy lines represent traditional approach via elemental bromine. The broken line represents the suggested approach of direct bromination.

of calcium bromide, and greatly improve the chances for successful price substitution of traditional drilling fluids. The thinking behind this approach of direct use of bromides as brominating agents may be applied to other cases where it may be found to be technically feasible.

Such a technological and scientific breakthrough, if achieved, can greatly facilitate diffusion of bromine derivatives through price substitution. It should be noted, however, that in principle integrated market structures of traditional materials producers and users can discourage diffusion in spite of considerable cost reductions. However, a threat in shortages either for political or technical reasons, may increase uncertainty associated with using traditional materials and cause price increases which can facilitate price substitution of the new entrant. In pursuing price substitution of calcium bromide for traditional drilling fluids or bromine derivatives for chlorine compounds, cost considerations are more important than market structure barriers to entry since in most cases producers and users do not display an integrated market structure. However, the important notion of costs of change should be included in assessing the potential for following the tactic of price substitution for each specific case.

## 6.6 Summary and Conclusions

The first major objective of this chapter was to propose a general framework that will assist the chemical producer in identifying growth opportunities through technological change.

For this purpose, the two principal modes of growth, that have emerged from the developmental pattern of basic chemicals outlined in Chapter 5, have provided the basis from which various strategies and tactics have branched. In this way, a technological growth tree has been formed.

A second major objective of this chapter was to demonstrate the applicability of the technological growth tree for pinpointing appropriate development options for basic chemicals producers, in a specific case of a particular bromine producer. As the underlying assumption of this study is (see Chapters 2 and 4) that development of the chemical industry largely depends on scientific research and technical progress, a subsequent objective was to exemplify the usefulness of the tree in identifying promising research areas worth further investigation, which may lead to appropriate directions for development for a particular bromine manufacturer.

It was concluded that the competitive and the conventional strategies can contribute little to the producer's goal of breaching the gap between his huge bromine production potential and the low demand. Therefore, the strategy of technological diversification, has been selected as the more viable alternative.

In applying the relevant tactics to bromine, the starting point was the indication of the under-utilised properties of bromine which are capable of producing property changes in various molecules. It has been shown in the chapter that this approach has resulted in several promising, though preliminary, research proposals worth further study.

In conclusion, the decision of an individual bromine producer to employ the technological growth tree implies broadening of the range of available opportunities as opposed to the ones suggested by conventional corporate strategy.

# CHAPTER 7

# CONCLUSIONS

The purpose of this chapter is to briefly review the conclusions of earlier chapters and to emphasize the main points.

The conventional corporate strategy literature emphasizes in the main financial strategies, whereas we have seen in the present study that technological strategies (particularly in the science-based industries), are an important factor explaining modern industrial growth and development.

## 7.1 Inadequacy of Conventional Corporate Strategy

Traditional corporate strategy writings have tended to focus their attention on the profit objectives and relegate the rest to a secondary position. By concentrating on the profit motive, the conventional approach ignores the need to reconcile conflict. This preoccupation with the profit objective directs attention to acquisition strategies, particularly expansion and portfolio diversification.

The expansion category employs acquisition strategies such as integrating forward and integrating backward, which aims to strengthen the competitive posture of the firm in its present area of operation in order to achieve a given profit ofjective.

The portfolio diversification category employs acquisition strategies that aim to remove the firm from its current field of activity and direct funds elsewhere.

Such a move can be taken for two principal reasons: (a) whenever analysis of the present area of operation shows that the firm's given profit objectives cannot be achieved therein; (b) in order to distribute commercial risk between several fields of activity.

In the event that the actual profit obtained by following either of these strategies exceeds the given profit objective, the latter is adapted upwards. However, when there is a failure to achieve the given profit objective, the latter is altered downwards.

It has been seen that exclusive attention to a single objective of profit and the consequent strategies makes the conventional corporate strategy approach adapt to circumstances rather than attempt to change them. This approach can be of some value to a firm of great financial strength having a given profit objective. But application of the conventional corporate strategy approach to firms having multiple objectives (as is often the case) and to firms of scientific and technological strength (in the science-based industries) in particular, is inadequate as we have demonstrated in Chapters 5 and 6.

## 7.2 Contribution of the Present Work

By contrast, the present study takes into account the existence of multiple corporate objectives, and proposes a synthesis of Cyert and March's and Williamson's models for reconciling them; at the same time, it recognises the special case of growth in a science based industry like the chemical industry, and recommends a framework which we refer to as the technological growth tree for tackling it.

## 7.3 Reconciliation of Conflict between Objectives

The schema for reconciliation of conflicting objectives is based on four reference standards, namely historical, external, intentional and innovative standards.

Essentially, trade-offs are resolved by setting each objective at two levels:

(i) a constraint level which represents the minimal requirement of the level of achievement for each objective, such that the coalition is preserved

(ii) a target level which represents the desired level of achievement for each objective as seen by its promoter in the coalition.

The difference between (i) and (ii) defines a margin within which trade-offs are feasible and conflicting claims may be satisfied. Both (i) and (ii) employ reference standards for their establishment. For the constraint level, both historical and external standards, which complement each other, should be used. Similarly, the target level can be set by using intentional and innovative standards.

It should be emphasised that whilst historical, external and intentional standards fit in well with conventional corporate strategy writings, innovative standards represent a significant departure as they perform a vital role in enforcing search for opportunities through scientific and technological progress.

## 7.4 The Technological Growth Tree

The proposed technological growth tree represents a conceptual framework which outlines development opportunities for basic chemicals that are generated by the application of scientific and technological knowledge.

The tree consists of two principal branches which respectively represent the competitive and innovative mode of growth.

### 7.4.1 The Competitive Mode

The competitive mode implies technological expansion (growth within existing end-use categories of the basic chemical) through two major strategies, technological competition and price competition. These strategies seek, through their corresponding tactics, to improve the competitive posture of an individual producer by the appropriate product or process innovations. It should be noted, however, that technological expansion does not have to exclude acquisition strategies. On the contrary, acquisition strategy such as integration forward can indirectly contribute toward technological expansion of a basic chemical producer as it brings the producer closer to problems and needs of the user. Such close association may lead to fruitful research collaboration for finding innovative solutions to common problems.

In conclusion, similarly to expansion by acquisition, technological expansion is appropriate in a growth situation but, unlike the former, its tactics may sometimes effectively employ scientific and technological knowledge to favourably change the circumstances of falling demand. However, in the event of generally declining demand for the basic chemical and the emergence of an oversupply situation, the competitive mode of the technological growth tree is of limited usefulness and its innovative mode should be employed instead.

### 7.4.2 The Innovative Mode

The innovative mode implies technological diversification through two major strategies: innovation of new end-uses and penetration into existing but unconventional end-use categories of the basic chemical. This is achieved by exploiting specific tactics discussed below.

#### 7.4.2.1 Innovation of New End-Uses

The strategy of innovation of new end-uses can be carried out only by the introduction of a major innovation which creates new needs within one or more of the six basic categories of social requirements: nutrition, shelter, health, clothing, communication and entertainment. A firm in a science-based industry close to the final consumer, is well placed to utilise this strategy. Suppose that a hypothetical firm producing television sets (a major innovation in its time) faces a severe overcapacity situation due to a general fall in demand for television sets: the traditional corporate strategy theory will suggest in such a case portfolio diversification into another, perhaps more profitable, area by acquisition. In practice, however, it is not easy to dispose of overcapacity in this way and to ignore the firm's accumulated scientific knowledge and technological expertise. The hypothetical firm may gain much more by an attempt to employ and develop its scientific and technological knowledge in research towards major innovations such as three dimensional television, or other innovations in the medical electronics or communication industries and in this create new social needs.

As far as a basic chemical producer is concerned, conventional wisdom regards such a producer as remote from the final consumer and hence does not expect him to be associated with major innovations of the kind mentioned above.

In contrast, the present study suggests that the crucial factor is not the distance from the end-consumer, but the scientific basis of the producer. Therefore the chemical producer should utilize its scientific background and participate (at least indirectly) in research, toward providing new needs, with a view to promote the effective application of his material.

#### 7.4.2.2 Penetration into Existing but Unconventional End-Uses

This strategy does not necessarily require the introduction of major innovations which imply creation of new social needs. The starting point is the existence of known needs which are presently fulfilled by traditional materials. The strategy aims to substitute those traditional materials by the basic chemical's derivatives and in this way to add new end-uses to the present end-use pattern of the chemical. As this strategy is associated with known needs, it is less demanding than the former strategy and can be more easily utilised. The two principal tactics under this strategy are price substitution and technological substitution.

(i) Price substitution

The simplest case of this tactic is where a potential new use of the chemical is fairly obvious, but its application is discouraged because of costs considerations. In such a case the tactic dictates research aimed at cost reducing processes. The research effort may be similar to the one required in the competitive mode and if successful will result in an increase of the total demand for the chemical. It should be noted that in the competitive mode up to the point where cross-elasticity of demand comes into effect, price competition can only increase the market share of the individual producer.

(ii) Technological substitution

Chemical research in this tactic seeks to utilise various properties of basic chemical and/or its derivative, in order to achieve technical superiority over traditional materials. This tactic can contribute toward a demand shift even if initially it achieves limited success in only special applications, as such beginnings may later serve as a basis for efforts to obtain price substitution.

## 7.5 Application of the Technological Growth Tree to Bromine

The application of the tree to a specific chemical should indicate development options in both the competitive branch and the innovative branch of the tree. As has been argued, the competitive mode is most useful when the industry faces a growing demand for the chemical. But whenever the demand declines, only the innovative mode can assist the chemical producer to breach the gap between falling demand and a persistent oversupply situation.

The analysis in Chapter 4 has shown bromine to be a basic chemical in oversupply, and has singled out a bromine producer which is strongly motivated to utilise its huge bromine production potential in spite of the unfavourable circumstances. Consequently, Chapter 6 concludes that the conventional corporate strategy approach, which adapts to circumstances, is inappropriate in this case and only the innovative branch of the technological growth tree can be useful. It has been shown that the most readily applicable strategy in this context is the penetration into existing but unconventional end-uses for bromine. The two major tactics of this strategy are price substitution and technological substitution. These identify key areas for research and suggest, for illustrative purposes only, a few promising research proposals worth further investigation.

### 7.5.1 Price Substitution for Bromine

The simplest case of this tactic is where new applications are obvious and bromine's use is discouraged due to costs considerations. This implies the need to reduce production costs. Hence, a key area for research would be the area of production processes. It has been argued in Chapter 4 that the oxidizing agent chlorine is the major cost item in bromine's production costs pattern. Thus following the tactic of price substitution implies departure from chlorine-based processes.

Two propositions therefore emerge:

(a) Direct research efforts toward oxidizing agents that will be more economic in use than chlorine.

(b) Investigate the possibility of producing desired bromine derivatives directly from a given bromide.

Note that proposition (a) displays the conventional wisdom that production processes should aim at elemental bromine production, while proposition (b) is more innovative in its approach as it by-passes the traditional intermediate stage of elemental bromine production.

It should be emphasized that in pursuing the tactic of price substitution, straightforward cost comparison between the bromine derivative and its substitute can serve only as a first approximation, since costs of change and overall long-term costs comparisons must be taken into account in order to assure successful substitution.

### 7.5.2 Technological Substitution for Bromine

This tactic suggests monitoring the property changes that the introduction of bromine into a molecule is expected to bring about in order to match the needs of an unconventional end-use category.

Consider, for example, the propellant industry. This industry uses fluorocarbons which are light gases that easily reach the stratosphere and destroy its protective ozone layer. This creates a need for propellants that do not reach the stratosphere so easily. The high specific gravity of bromine suggests that introduction of bromine into a fluorocarbon molecule may result in a new, heavier propellant which would not reach the stratosphere. This tactic of using bromine for increasing the specific weight of propellants, represents a growth and development opportunity suggested by the present study.

Another example is the polyester industry. One of the building blocks of the industry is terephthalic acid, which is the para isomer of a dicarboxilic aromatic acid. We have already noted in Chapter 6 that two bromine properties have been shown to be relevant in this context: (i) the stereospecifity it produces in its aromatic derivatives; (ii) the recently discovered carbon-bromine bond reactivity toward carbon dioxide. These properties suggest that the possibility of a new process based on bromine as a raw material in the production of terephthalic acid could result in a more efficient process and a new outlet for bromine.

In conclusion, it has been shown that the technological growth tree approach for basic chemicals, through its technological expansion and diversification strategies, is more powerful than the conventional corporate strategy approach. It should be noted, however, that as the former relies on scientific and technological knowledge, its application in a specific science-based industry, requires thorough understanding of the relevant scientific discipline.

Nevertheless, although this study has concentrated on chemistry, in principle a similar growth tree that comprises technological expansion and diversification strategies that rely on other scientific disciplines (e.g., solid state physics (electronics)) can be outlined for any science-based industry.

In general, this approach is therefore most appropriate to cases where product and process developments are required. In these instances, the conventional corporate strategy approach is of limited use due to its exclusive attention to acquisition and portfolio diversification strategies.

# NOTES AND REFERENCES

## CHAPTER 1

1. For example see: I.H. Ansoff, Corporate Strategy, Penguin, Harmondsworth, 1968, Chapter 3. In this chapter, Ansoff mentions social objectives as well as economic ones but concludes that: "the economic objectives exert the primary influence on the firm's behaviour."
2. Compare with: F.M. Scherer, Industrial Market Structure and Economic Performance, Rand McNally, Chicago, 1970, in particular p. 346. There Scherer argues that from the 19th century until the 1950's the mainstream of economic theory was insensitive to the phenomenon of technological change. Emphasis was on the result of combining labor and capital with static production functions, and technological change was no more than a side show attraction. After 1957, however, economists have generally accepted that growth output per worker is mainly due to technological change.
3. The formal approach is predominant in the traditional corporate strategy literature. The major advocate, however, who has proposed the most comprehensjve corporate strategy model, is I.H. Ansoff (reference 1).
4. The informal approach is represented by C.E. Lindblom, "The Science of Muddling Through", in H.I. Ansoff (ed.), Business Strategy, Penguin, Harmondsworth, 1968.

## CHAPTER 2


1. S. Tilles, "How to Evaluate Corporate Strategy", H.B.R. July/August 1963. Similar definitions are given in:

   J.T. Cannon, Business Strategy & Policy, Harcourt, Brace & World, Inc., 1968, p. 9.

   H.N. Broom, Business Policy & Strategic Action, Prentice-Hall, Inc., N.J., 1969, p. 44.

   B. Wagle, "Management Science & Strategic Planning", in: A Handbook of Strategic Planning, B. Taylor (ed.), 1972, p. 380.
2. I.H. Ansoff, Corporate Strategy, Penguin, 1968, pp. 105-107.
3. R. Ackoff, A Concept of Corporate Planning, Wiley Interscience, 1970, p. 5.
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   (d) R.F. Steward and M.D. Doscher, "The Corporate Development Plan", Report No. 183, Sept. 1963, Industrial Economics Division, Menlo

Park, California, Stanford Research Institute.

6. Cf. P.H. Grinyer, "The Anatomy of Business Strategic Planning Reconsidered", The Journal of Management Studies, Vol. III, No. 2, p. 199, 1971, for a detailed review of the early models in strategy formulation.

7. H.I. Ansoff, Corporate Strategy, Penguin, 1968.

8. J. Argenti, Systematic Corporate Planning, Nelson, London, 1974.

9. This is not at all dissimilar to Chandler's thesis that strategy follows structure. Cf. A.D. Chandler Jr., Strategy and Structure, The MIT Press, 1964, pp. 13-14.

10. Cf. J. Argenti, A Practical Guide to Corporate Planning, Allen and Unwin, London, 1969.

11. Such a mechanistic organization is described by Burns. See T. Burns "Mechanistic and Organismic Structures", reproduced in Organisation Theory, (ed.) D.S. Pugh, Penguin Books, 1971.

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36. W.R. Stumpe, "Entrepreneurship in R&D - A State of Mind", Research Management, Vol. XXV, No. 1, Jan. 1982.

37. "Industrial R&D Strategy and Management - A Challenge for the 1980's" R&D Management Vol. 10, Special Issue, 1980, p. 180.

38. F.R. Bradbury and B.G. Dutton, Chemical Industry: Social and Economic Aspects, Butterworth, London, 1972.

39. E. Mansfield, Industrial Research and Technological Innovation, Norton N.Y., 1968, p. 55.

40. F.M. Scherer, Industrial Market Structure and Economic Performance, Rand McNally, Chicago, 1970, p. 355.

41. N.W. Chamberlain, Enterprise and Environment: The Firm in Time and Place, McGraw-Hill, N.Y., 1968.

42. S.P. Blake, Managing for Responsive Research and Development, W.H. Freeman, San Francisco 1978.

43. However, it should be noted that Blake is not the only one to discuss these two screening methods, compare: A. Baines, F.R. Bradbury, C.W. Suckling, Research in the Chemical Industry, Elsevier Publishing Co. Ltd., London, 1969, Chapter 4.

44. F.R. Bradbury, W.M. Gallagher, C.W. Suckling, "Quantitative aspects of the evaluation and control of research and development projects", R&D Management 3, 2, 1973, p. 49.

45. F.R. Bradbury, M.C. McCarthy and C.W. Suckling, "Patterns of Innovation - The Bipyridyl Herbicides", Chemistry and Industry, 1972, pp. 195-200.

46. Compare with Reference 44.

47. E.P. Learned, F.J. Aguilar and R.C.K. Valtz, European Problem in General Management, Homewood, Ill., 1963.

48. Ibid.

49. W.Fellner, "The Influence of Market Structure on Technological Progress", Quarterly Journal of Economics, November 1951, pp. 500-567.

50. W.E.G. Salter, Productivity and Technical Change, University of Cambridge Press, 1966, p. 90.

51. F.M. Scherer, Industrial Market Structure and Economic Performance, Rand McNally, Chicago, 1970, pp. 368-370.

## CHAPTER 3

1. For an outline of Argenti's approach see page , Chapter 2.
2. I.H. Ansoff, Corporate Strategy, Penguin, Harmondsworth, Middlesex, England, 1968.
3. K.R. Andrews, "Public Responsibility in the Private Corporation", The Journal of Industrial Economics, Vol. XX, No. 2, April 1972, pp. 135 - 145.
4. B. Lowes and J.R. Sparkes, "Social Responsibility Accounting", Journal of Business Policy, Vol. 3, No. 4, 1973.
5. J. Humble, "A Practical Approach to Social Responsibility", Management Review, Vol. 67, No. 5, 1978.
6. R.M. Cyert and J. March, A Behavioral Theory of the Firm, Prentice-Hall, Inc., N.J., 1963.
7. O.E. Williamson, The Economics of Discretionary Behavior: Managerial Objectives in a Theory of the Firm, Prentice-Hall, Inc., N.J., 1964.
8. Reference 6, p. 29.
9. Ibid., p. 32
10. Ibid., p. 118
11. B.J. Loasby, Choice, Complexity and Ignorance, Cambridge University Press, Cambridge, 1976, p. 142.
12. Ibid.
13. Ibid.
14. Ibid., p. 143
15. Actually Cyert and March argue that conflict is never fully resolved within the organization because of the form of the goals and the way in which they are established. Reference 6, P. 43
16. B.J. Loasby, "An Analysis of Decision Processes", R&D Management, Vol. 4(3), 1974, p. 149.

·.J. Sutton, "Behavioural Theory of Diversification", Scottish Journal of Political Economy, Vol. XX, No. 1, pp. 33-34.

18. Reference 7, p. 33.

19. Reference 11, p. 118.

20. Ibid., p. 119; Loasby refers to an article by H. Leibeinstein, "Allocative Efficiency vs. X-Inefficiency", American Economic Review, LVI, 1966, pp. 392-415.

    There Leibenstein introduces X-inefficiency as representing most of what is commonly meant by inefficiency: everything beyond the distortions attributable to market imperfections. Loasby admits that Leibenstein's claim that welfare losses due to such slack in the system are far greater than the losses resulting from the misallocation inherent in imperfect markets has been disputed; however, Loasby asserts that it is not the significance but the logic of the argument which is at issue here.

21. Reference 6, p. 36.

22. Ref. 7, p. 36. Thus Williamson argues that "the stockholders may frequently lack sufficient information, organized power, and determination to compel the management to maximise profits. However, they are not totally ignorant, completely fractionated, or entirely passive. Thus they will ordinarily be in a position to mobilise their forces should profit fall below some minimum acceptable level... 'discretionary profit' is defined as that amount by which earnings exceed this minimum performance constraints."

23. Reference 16, p. 151. The historical, external and planning standards are due to W.F. Pounds, "The Process of Problem Finding", Industrial Management Review, Vol. 11, No. 1, 1969.

    The fourth category, imaginative, was proposed by C.W. Suckling in a private communication.

24. Reference 17, p. 33.

25. Reference 11, p. 100

26. See Reference 23.

27. Reference 16, p. 152.

28. C.R. Christensen, K.R. Andrews, J.L. Bower, *Business Policy, Text & Cases*, Homewood, 3rd edition, Irwin, 1973, p. 866

29. "A Study of U.K. Nationalised Industries - Their Role in the Economy and Control in the Future", *NEDO*, London: HM Stationery Office, 1976, p. 9.

30. Guidelines for Project Evaluation, *UNIDO*, New York, 1972, pp. 213-231.

31. Reference 11, p. 140.

32. *Ibid*., p. 137. This type of thinking is similar to the one exhibited by the research director, described by Loasby, who "in an attempt to inhibit the subtle censorship of current ideas told his scientists that 'the objective of the Research Department is to change corporate strategy'."

## CHAPTER 4

1. The textbook consulted in preparing the general background section is the most extensive work on bromine published so far. Z.E. Jolles (ed.), Bromine and Compounds, Ernest Benn Ltd., London, 1966.

2. For a good summary of bromine's physical properties, see Kirk-Othmer Encyclopedia of Chemical Technology, 3rd edition, Vol. 4, 1978, p.227
A detailed description of physical and chemical properties can be found in Reference 1, Part I, Chapters 2 and 3.

3. C.T. Pumpelly in reference 1, Part I, Chapter 3, pp. 51-60.
For a comprehensive survey of inorganic bromine compounds see: P.H.O. John, ibid., Part II, Chapter 1, pp. 81-145.
P.J.M. Radford and M. Schmeisser, ibid., Part II, Chapter 2 pp. 147-152.
P.J.M. Radford, ibid., Part II, Chapter 3, pp. 179-254.
A more recent, good, concise summary of inorganic bromine compounds can be found in: V.A. Stenger, in Kirk-Othmer Encyclopedia of Chemical Technology, 3rd ed., Vol. 4, pp. 243-249, 1978.

4. C.T. Pumpelly in reference 1, Part I, Chapter 3, pp. 60-78. For the discussion in greater detail of the fundamentals of organic reactions of bromine and for practical examples, see:
M.D. Johnson, ibid., Part III, Chapter 1, pp. 255-318.
C.T. Pumpelly, ibid., Part III, Chapter , pp. 318-351.
Z.E. Jolles, A.H. Oxtoby and P.J.M. Radford, ibid., Part III, Chapter 3, pp. 351-407.
A more recent concise summary of organic bromine compounds can be found in: V.A. Stenger, Kirk-Othmer Encyclopedia, 3rd ed., Vol. 4, 1978, pp. 249 - 263.

5. Reference 1, Part V, pp. 487-521. For a detailed account of the biological aspects of bromine and compounds, the reader is referred to: G. Booth, ibid., Part VI, Chapter 1, pp. 521-554.

H. Farkas-Himsley, ibid., Part VI, Chapter 2, pp. 554-563.

G.M. Segelman, ibid., Part VI. Chapter 3, pp. 563-589.

6. Reference 1 Part VI, Chapter 6.

The inhibitory action of bromine and its compounds is thought to involve both the bromine atom and hydrogen bromide, although the latter is believed to be the active species, as it reduces the concentration of the OH and H radicals which are involved in the oxidation of carbon monoxide.

$$OH + CO \rightarrow CO_2 + H$$
$$H + O_2 \rightarrow OH + O$$

The bromine atom serves to regenerate HBr according to the following mechanism:

$$HR^1 + Br \rightarrow HBr + R^1$$
$$R^2 + HBr \rightarrow Br + HR^2$$

where $HR^1$ refers to $CH_2O$, HCO, etc., while $R^2$ represents H, OH, $CH_3$, etc. It thus becomes necessary to remove the bromine from a given compound in order that the atom may participate as an inhibitor in the flame reaction.

7. V.A. Stenger, Kirk-Othmer Encyclopedia of Chemical Technology, 3rd Ed., Vol. 4, 1978, p. 249.

8. A more detailed description of the various sources of bromine is presented in reference 1 p.4 - 11.

9. Bromine U.S. Bureau of Mines (USBM), U.S. Government Printing Office, 1981.

10. The following sources were consulted:

 (a) Reference 1 p.20 - 32

 (b) C.E. Reineke, Kirk-Othmer Encyclopedia of Chemical Technology, 3rd Ed. Vol. 4, 1978 p.233 - 237.

 (c) Reference 9, p.3.

11. Reference 1, p.39 - 40.

12. The principal sources consulted for this section were:

 (a) Reference 1, pp. 521 - 730.

 Applications of bromine are extensively described therein and the range of uses has not changed since 1966. However, the relative importance of bromine's end-use categories is recently undergoing changes, particularly in the field of fuel additives. This and other restrictions on bromine compounds, e.g. in fire-retardants, are a result of the rise of environmental awareness almost unknown when the book was written.

 (b) Reference 9, p.2 - 3

 (c) A report on bromine prepared by The Research Department, Kidder, Peabody & Co., May 1982 p.28-33.

 (d) Other sources include:

 (i) Bromine World Survey of Production Consumption and Prices; Roskill Information Services Ltd., London 1975.

 (ii) Chemical Products Synopsis, A Reporting Service of Mannsville Chemical Products, New York, May, 1978.

(iii) Mineral Commodities Summary, U.S. Bureau of Mines (USBM), U.S. Department of the Interior, 1978.

(iv) USBM Minerals Yearbook "Bromine", U.S. Department of Interior, 1976.

(v) R.H.J. Forster, "Mineral Industry Surveys - Bromine in 1978", USBM, U.S. Department of the Interior, 1978.

(vi) European Chemical News, June 2, 1978.

(vii) Chemical Age, 5 May, 1978.

(viii) An expert's opinion regarding the future of the bromine industry was published by M. Wilsker, "What next for bromine and its compounds", European Chemical News, 22 October, 1976. This is an interesting article outlining important factors affecting the re-alignment of the bromine industry. These were described as including richer resources (brines), shipment, polymer production technology, increasing use in water treatment and in agriculture. However, the article may be criticised for the very little attention it pays to health and environmental considerations (in spite of its relatively recent date of publication) and its total dis-regard for the increasingly important use of calcium bromide in heavy competition fluids for gas and oil wells.

13. According to 12 (d) (i), p. 27-30.

14. Chemical Product Synopsis, A Reporting Service of Mannsville Chemical Products, New York, March 1982.

15. Reference 9, p.7.

16. Reference 12(c) p.28

17. See reference 14.

18. Reference 12(c) p.31

19. Reference 9, p.8

20. Reference 12(d)(v)

21. Reference 14

22. Reference 12(c) p.29

23. J.F. Mills, Disinfectants: Water Wastewater, 113, 1975

24. D.R.R. Grothe and J.W. Eaton, Trans. Am. Fish Soc. 104, 800, 1975

25. Reference 12(c) p.32 - 33.

26. Ibid. p.30 - 31

27. Reference 9, p.8

28. Reference 12(c) p.33

29. Reference 14

30. Reference 9, p.8

31. As there is no organization of bromine producers, very little data is published. Moreover, none of the main producing countries publish satisfactory statistics. The U.S., for instance, has no export figures for bromine and its compounds at all. These figures are aggregated under a general heading, "Crude Minerals N.E.C." and it is impossible to isolate data for bromine. However, an idea about the bromine situation can be obtained from publications of U.S. agencies such as the U.S. Bureau of Mines, trade journals and surveys published by consulting firms. These sources are used here but are not very reliable, as they are not based on hard data, which is difficult to obtain, but on their expert's estimates. Such information can therefore service only as an indication to the real situation.

32. Reported in Israel Industry and Commerce, Vol. XXVIII, No. 4 September 1977.

33. Bromine, Goldman Sachs Research, New York, 1976, p.9

34. The Jerusalem Post, April 13, 1983, p.6

35. The range of prices is based on the trade list price in the U.S. quoted in reference 14.

36. Based on information obtained from DSB's Marketing Department.

37. Ibid.

## CHAPTER 5


1. A. Baines, F.R. Bradbury, C.W. Suckling, Research in the Chemical Industry, Elsevier Hd., London, 1969.

2. E. Mansfield, J. Rapoport, A. Romeo, E. Villani, S. Wagner, F. Husic, The Production and Application of New Industrial Technology, W.W. Norton, New York, 1977, p.12.

   See also: I.U. Nasbeth and G.F. Ray (eds.), The Diffusion of New Industrial Processes, Cambridge University Press, 1974.

3. E.M. Rogers and F.F. Shoemaker, The Communication of Innovations. The Free Press, New York, 1971. This book provides a review of literature in the various disciplines together with an appropriate bibliography.

4. E. Mansfield, Reference 1, p. 117.

5. D. Schon, Beyond the Stable State, Temple Smith, 1971, p. 108.

6. E. Mansfield, (a) Reference 1.
   (b) The Economics of Technological Change, W.W. Norton, 1968.

7. Reference 6b, p. 113.

8. W.E.G. Salter, Productivity and Technical Change, Cambridge University Press, 1969.

   The simple model rests on the following assumptions:

   (i) Plants are indivisible, homogeneous, specific units and cannot be adapted to other techniques.

   (ii) The market is a perfectly competitive one.

   (iii) All plants work at designed normal capacity.

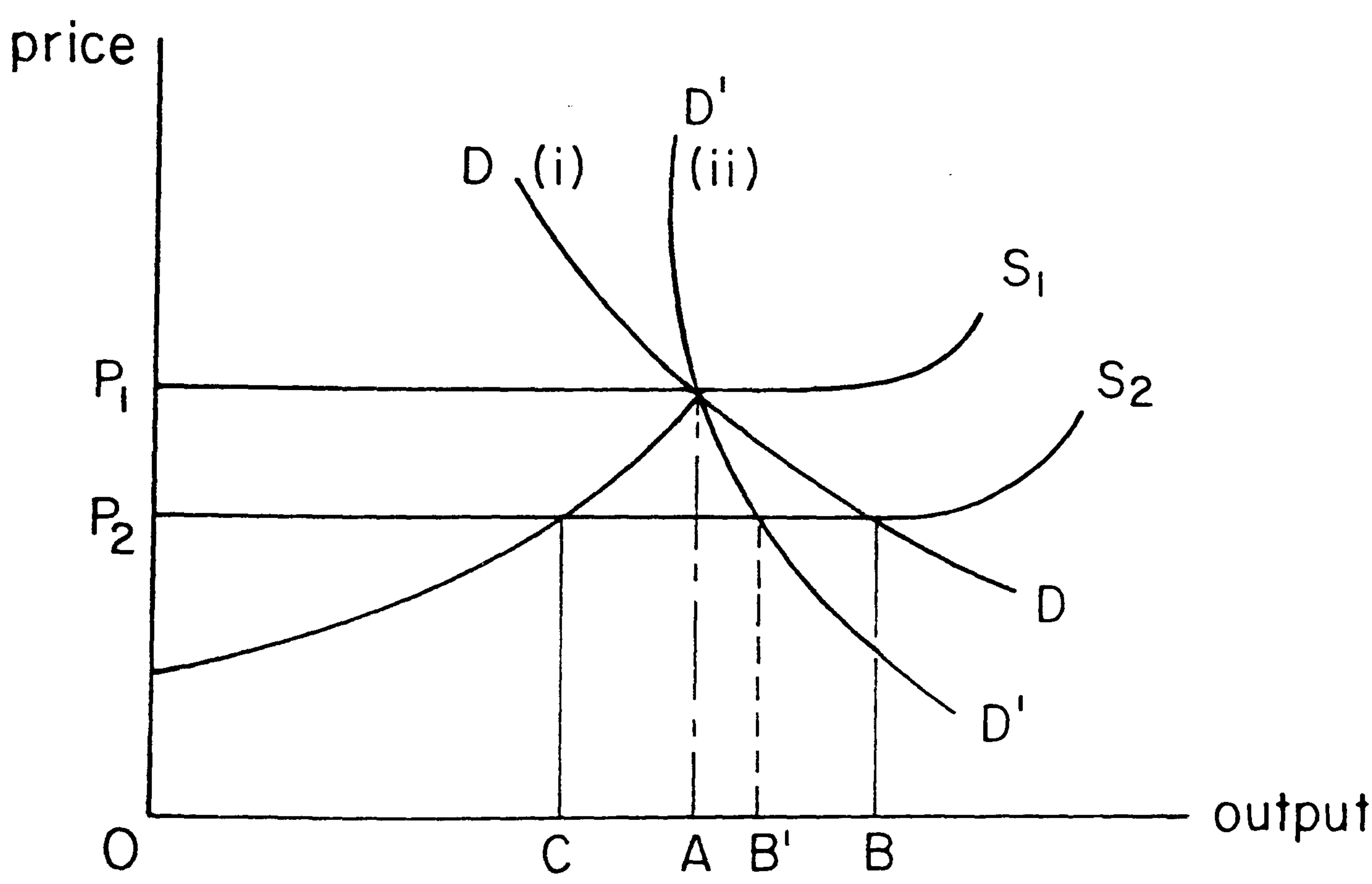
   (iv) Labour and managerial efficiency are equal in all plants.

   Chapter IV, particularly pp. 50-52.

Salter argues that most of these assumptions are not critical except the one regarding perfect competition. Indeed he considers three departure which affect the operation of his simple model. These are: monopoly, market segmentation and oligapoly.

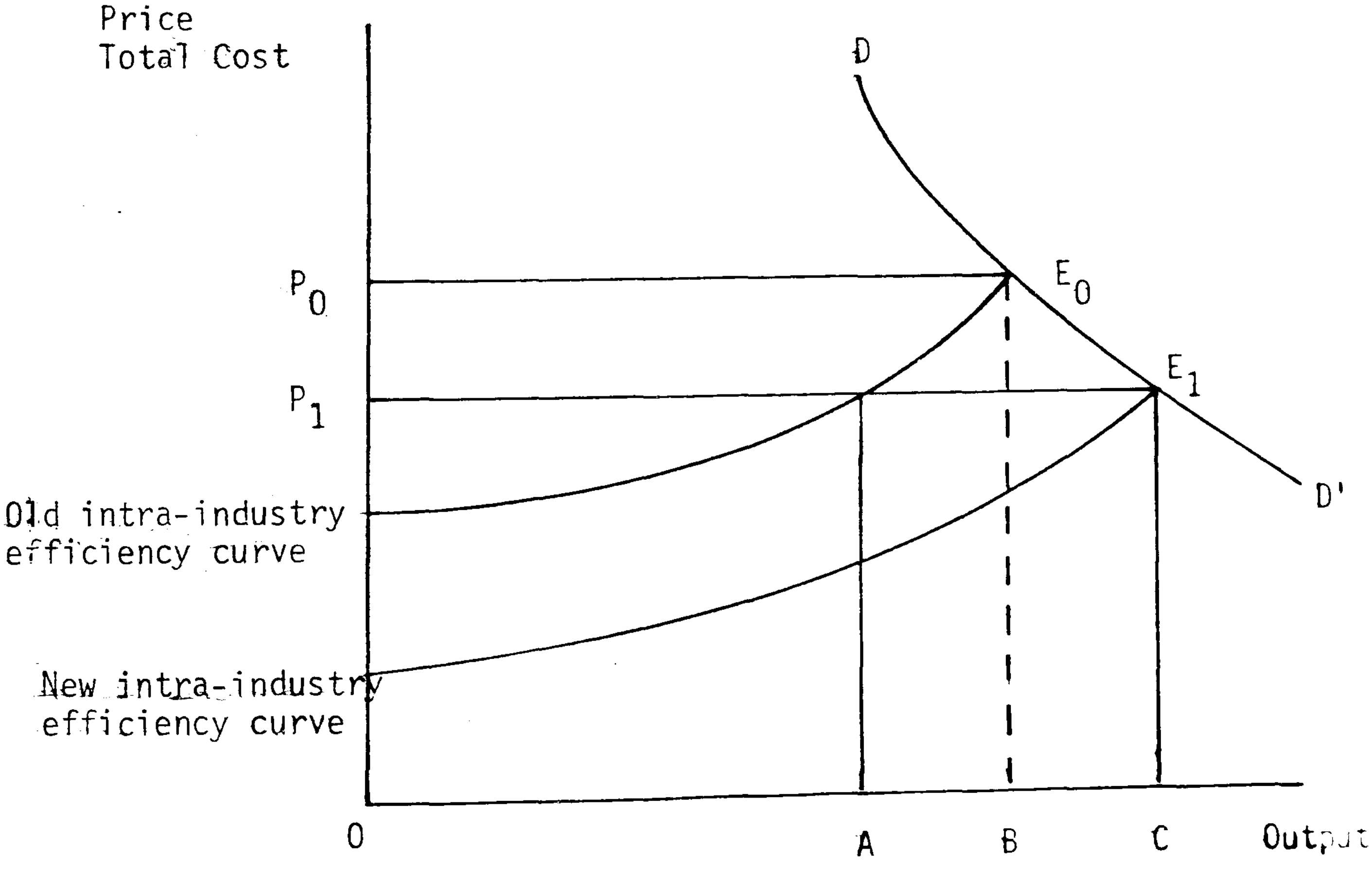
Chapter VII, in particular pp. 90-94.

9. Ibid. pp. 80-81: Salter asserts that whilst price movements depend on rates of improvements in the new technique, output can be also affected by externally determined demand. Two aspects of such externally determined demand are considered to influence the net addition to output made by a new advantageous technique. These are the price elasticity of demand and shifts in demand. The following figure illustrates effects of: (i) a high price elasticity of demand curve (DD), (ii) low price elasticity (D'D') of demand curve,



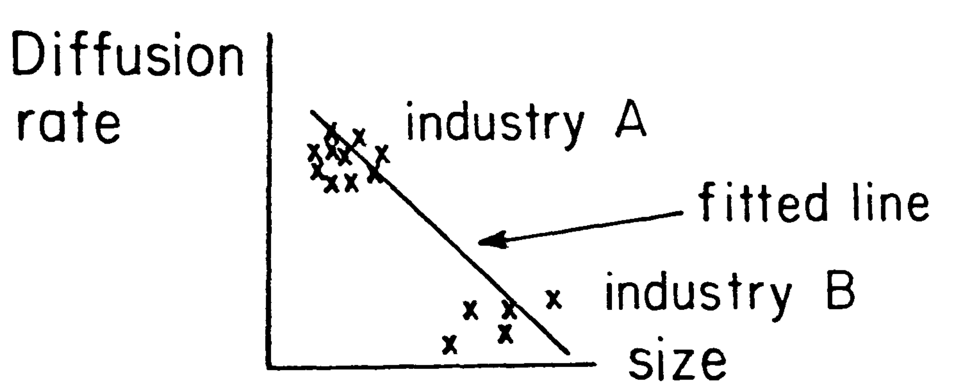
The new technique reflects itself in a new supply output curve $S_2$ which saves total costs and lies below $S_1$ which represents the old technique. Now consider (i): prices fall to $P_2$ and total output will be OB. Old plants whose operating costs exceed the new equilibrium level of prices $P_2$ are eliminated. The total amount of new technique's capacity is CB of which AC effectively replaces the absolute capacity and AB is a net addition to the output of the industry. For (ii) the new capacity constructed corresponds to $CB^1$. Note that demand elasticity does not affect replacement of outmoded plants; in either case the replaced capacity is AC. However the net additional capacity $AB^1$ is lower for low price elasticity of demand. Thus high elasticity of demand has the potential to facilitate output expansion. It may be added that a positive shift of the demand curve (to the right) will similarly favour expansion.

10. The incorporation of total new processes in the industry's scheme of output can be shown in the following figure:



The effect of a new process will be to reduce prices from $P_0$ to $P_1$. The new price $P_1$ may be lower than operating costs of some old plants. These may be replaced by plants using the new process which result in output AB. Given the demand curve DD' the total output required at price $P_1$ will be C. Hence there will be an additional increment BC to total output. Thus OA represents old plants still in operation, AB represents portion of scrapped plants and AC represents total new plants. AC can be interpreted as Mansfield's equilibrium level of use of the innovation.

11. E. Mansfield, Reference 6b, p. 119.
12. E. Mansfield, Reference 6b, p. 126.
13. Ibid. p. 120.
14. It should be noted however that under the assumption of profit maximization, Salter maintains that there is no reason why a monopolistic market structure should discourage adoption of a new technique.
15. E. Mansfield, Reference 6b, pp. 123-125.
16. S. Davies, The Diffusion of Process Innovations, Cambridge University Press, Cambridge, 1979.
17. Ibid. pp. 22-23 where Davies makes his point about the difficulty in interpretation caused by Mansfield's statistical treatment, by considering the hypothetical situation depicted in the following figure:



Industry A, comprising a few large firms, adopts its innovations quicker than industry B, which comprises many small firms. Even if there is no relationship between firm size and speed of adoption within each industry, a regression line fitted to the pooled data for both industries will clearly be downward sloping, apparently indicating an inverse relationship between firm size and rate of diffusion.

18. Compare with E. Mansfield in a relatively recent work (reference 1, p. 135) where the importance of a non-economic behavioural feature such as "progressiveness of management" as a determinant of the rate of adoption of an innovation is acknowledged.

19. See reference 6b, p. 113.

20. In this context it is important to mention two pieces of independent research:

    (a) E. Mansfield,"Technical Change and the Rate of Imitation", Econometrica, 1969.

    (b) J.S. Metcalfe, "Diffusion of Innovations in the Lancashire Textile Industry", Manchester School, June 1970.

    Mansfield, investigating the diffusion of twelve innovations has concluded that his symmetrical logistic curve (which resembles Davies' comulative normal curve) is in good agreement with his data. Metcalfe, on the other hand, has found out that the skewed logarithmic reciprocal transformation (which is similar to Davies' cumulative lognormal) is in accord with the data for his three innovations. Davies convincingly asserts that this apparent conflict may be resolved by using the concepts proposed in his model. Thus the technical descriptions of the innovations, as provided by Mansfield and Metcalfe, confirm that the former's innovations are mainly group B, whereas the latter's are all group A.

21. Reference 16, p. 162.

22. See no. 19 above.

23. Reference 16, p. 160.

24. See Reference 15.

25. Reference 16, p. 141.

26. Ibid. pp. 141-142

27. B. Gold "Technological Diffusion in Industry: Research Needs and Shortcomings". *The Journal of Industrial Economics*, Vol. XXIX No. 3, March 1981, p. 247 - 269.

28. J.S. Metcalfe "Impulse and Diffusion in Technical Change". *Futures*, Vol. 13, No. 5, October 1981. p. 347 - 359.

29. *Ibid*. p. 354-6.

30. B. Gold *Explorations in Managerial Economics: Productivity, Costs, Technology and Growth*, Macmillan, London 1971. p. 213 - 215.

31. J. Langrish, M. Gibbons, W.G. Evans and F.R. Jevons *Wealth from Knowledge*, Macmillan, London 1972.

32. J. Jewkes, D. Sawers and R. Stillerman, *The Sources of Invention*, 2nd Edition, Macmillan, London 1969. p. 169 - 177.

33. F.M. Scherer, *Industrial Market Structure and Economic Performance*, Rand McNally, Chicago 1970. p. 350.

34. B.C. Twiss, *Managing Technological Innovation*, Longman, London 1974, 1980. Chapters 1 - 2.

35. C.T. Hill in Chapter 1 of *Technological Innovation for a Dynamic Economy*, edited by C.T. Hill and J.M. Utterback. Pergamon Policy Series, 1979. p. 27 - 28.

36. Thus Japan's total expenditures on R&D is more than that of France and UK, but is still below that of West Germany, USSR and USA. Moreover, Japan allocates more manpower to R&D both in absolute and relative terms, than West Germany, France and UK, and only less than USSR and USA.

Hajime Eto, "Problems and Lessons of Japanese Technology Policy" R&D Management, Vol. 10, No. 2, Feb. 1980.

37. V. Dembo, "Technology Transfer Planning", R&D Management, Vol. 9, No. 3, June 1979.

38. Rogers sees diffusion as "the human interaction in which one person communicates a new idea to another person. Thus, at its most elemental level of conceptualization, the diffusion process consists of (1) a new idea, (2) individual A who knows about the innovation, and (3) individual B, who does not know about the innovation...".

Everrett Rogers, Diffusion of Innovations, The MacMillan Co., 1962, pp. 13-14.

39. D. Schon, Beyond the Stable State, Random House New York, 1971. In particular, see Chapters 4 & 5.

40. E. Hassinger, "Stages in the Adoption Process", Rural Sociology, 24, 1959, pp. 52-53.

41. E.M. Rogers, Reference 3, pp. 137-157.

42. Ibid. p. 139.

43. D. Schon, Reference 5, p. 32.

44. T.S. Kuhn, The Structure of Scientific Revolutions, The University of Chicago Press, 1962.

45. See Reference 5, p. 128.

46. G. Zaltman, R. Duncan, Strategies for Planned Change , John Wiley & Sons, 1977, in particular Chapters 9 - 11.

47. E.M. Rogers, F.F. Shoemaker, Communication of Innovation: A Cross Cultural Approach ,New York, The Free Press 1971, p. 127. Here a change agent is defined as "... a professional who influences innovation decisions in a direction deemed desirable by a change agency".

48. S. Sands "Using Adoption and Diffusion Theory to Improve the Odds of New Product Success". Illinois Business Review, Vol. 38, March 1981, p. 6-10.

49. D.M. Freeman, H. Azadi, M. Lowdermilk "Power Distribution and Adoption of Agricultural Innovation: A Structural analysis of Villages in Pakistan". Rural Sociology, Vol. 47, No. 1, Spring 1982, p. 68-81.

50. The properties of a polymer are related to its tendency to crystalize. In thermodynamic terms this tendency may be identified with the free energy charge accompanying it. This is made of two terms:

$\Delta G$ Crystalization = $\Delta H$ Crystalization - $T\Delta S$ Crystalization

The enthalpy term is the strength of the intermolecular bonds which are formed as the polymer molecules come together, and the entropy term represents the effect of molecular steric hindrances to the neat packing of the molecules into a crystaline structure.

If $\Delta H$ is large, over 5 kcal/mole per 0.5 nm length of chain, then the polymer is said to have properties of a fibre. Between 2-5 kcal/mole plastic properties would be expected and under 2 kcal/mole an elastomer should result. Temperature and $\Delta S$ tend to change this; bulky side chains will cause a polymer to be more elastomeric than expected on the basis of $\Delta H$; raising temperature also tends to make a polymer more elastomeric.

On the basis of the above considerations, the effect of an increasing number of chlorine atoms on a series of polymers can be shown:

Polyethylene

$$\begin{array}{ccccccccccccc} & H & & & & H & & & & H & & & \\ - & C & - & CH_2 & - & C & - & CH_2 & - & C & - & CH_2 & - \\ & H & & & & H & & & & H & & & \end{array}$$

P V C

$$\begin{array}{ccccccccccc} & Cl & & & & Cl & & & & Cl & \\ - & C & - & CH_2 & - & C & - & CH_2 & - & C & - \\ & H & & & & H & & & & H & \end{array}$$

Polyvinyliden

$$\begin{array}{ccccccccccc} & Cl & & & & Cl & & & & Cl & \\ - & C & - & CH_2 & - & C & - & CH_2 & - & C & - \\ & & & & & Cl & & & & Cl & \end{array}$$

The first material, polyethylene, contains no chlorine. Consequently there are low intermolecular forces resulting in a low melting point. On $\Delta H$ grounds alone, it would be an elastomer, but due to the entropy term ($\Delta S$) reflecting the compact packing of chains, polyethylene belongs to the class of plastics. The chlorine atom introduced in PVC induces high dipole-dipole bonds thus increasing $\Delta H$ and therefore PVC is a plastic. A second chlorine atom as in Polyvinyliden Chloride magnifies this effect by further increasing $\Delta H$ thus moving Polyvinyliden Chloride into the fibres category.

For a more detailed analysis of the subject see:

(a) A.D. Jenkins and A. Ledwith (eds.) Reactivity, Mechanism and Structure in Polymer Chemistry. Chapter 16 by K.J. Ivin, pp. 532-535. John Wiley & Sons, London, 1974.

(b) J.K. Stille, Introduction to Polymer Chemistry, Chapter 3 and 9, particularly pp. 162-164.

51. Kirk - Othmer, Encyclopaedia of Chemical Technology, 2nd edition, 1964, Vol. 3, p. 751.

52. Reference 2, p. 118.

53. (a) W.L. Faith, D.B. Keyes, R.L. Clarck, Industrial Chemicals, 3rd edition, J. Wiley & Sons, New York, 1966, pp. 248-257.

(b) D.L. Taylor, "Production and Use Patterns" in Chlorine, Its Manufacture Properties and Uses, edited by J.S. Sconce, Reinhold Publishing Co. New York, 1962.

54. A.S. Kastense "Vinyl Chloride" in Reference 38b,p. 781-805.

55. Compare with the remark that N.W. Chamberlain has made in Enterprise and Environment, McGraw-Hill, New York, 1968, p. 63.

56. The emergence of the polymer industry was preceded by the birth of a new scientific paradigm - the macromolecular theory - this and the contribution to polymer science is described by the developer himself, H. Staudinger, in the book From Organic Chemistry to Macromolecules, Wiley Interscience, New York, 1970.

# CHAPTER 6


1. The power factor (or Lang factor) applied to plant capacity ratio is widely known in chemical engineering and may appear in different methematical forms. In M.S. Peters & K.D. Timmerhause, Plant Design and Economics for Chemical Engineers, second edition, McGraw Hill, 1968, p. 122, it is formulated as $Cn = C(R)^x$, but in a slightly modified form it could be expressed as:

$$C_1/C_2 = (S_1/S_2)^b$$

where $C_1$ represents plant capital cost at plant capacity $S_1$, $C_2$ is cost at capacity $S_2$ and b is an exponent satisfying: $0<b<1$. This means that if one wishes to double plant capacity so that $S_2=2S_1$, it would not be necessary to double investment costs but just to multiply it by $2^b$ and get $C_2 = 2^b C_1$. (Of course, $0<b<1 \rightarrow 2^b<2$).

2. D.S. Davies, "The Changing Nature of Industrial Chemistry", C & EN, March 6, 1978, pp. 22-27.
3. Social and economic problems associated with exploiting economies of scale in large chemical plants were discussed in the chemical industry. For example: U. Colombo and G. Lanzavecchia, "Criteri di scelta della Potenzialita degli impianti chimici", Montedison SPA, Milano, 27 October 1972.
4. See note 9 in Chapter 5.
5. Compare with H. Levy and M. Sarnat, Capital Investment and Financial Decisions, Prentice-Hall, N.J., 1978, pp. 157-159.
6. Compare with A. Baines, F.R. Bradbury, C.W. Suckling, Research in the Chemical Industry, Elsevier Hd., London, 1969, p. 39.
7. W.L. Faith, D.B. Keyes, R.L. Clarck, Industrial Chemicals, 3rd ed.,

J. Wiley & Sons, N.Y., 1966, pp. 248-257.

8. See note 36 in Chapter 5.

9. Compare with reference 6, p. 36.

10. Compare with ibid., p. 37.

11. See ibid., pp. 36-39.

12. W.L. Faith, D.B. Keyes, R.L. Clarck, Industrial Chemicals, 3rd ed., J. Wiley and Sons, N.Y., 1966, pp. 248-257.

13. For a concise account on the place of bromine in the theory of photography see: L.F.A. Mason, "Photography", Part VI, Chapter 7 in J.E. Jolles (ed.), Bromine and Compounds, Academic Press, London, 1966.

14. From J. Scone (ed.), "Chlorine, its Manufacture...", N.Y., 1962, p. 15.

15. N. Holleman, "Recherches Quantitative sur Benzenes Halogenes", Rec. Travaux Chim. P B, 30, 1911, pp. 305-322.

16. H. Pines, et al. (eds.), Advances in Catalysis, Vol. 28, N.Y., 1977, p. 331.

17. See U.S. patent no. 3484198, 1969.

18. G. Campbell, DDT, London, 1950.

19. Non-chlorine processes have been described by F. Yaron in Chapter 1 of Z.E. Jolles (ed.), Bromine and Compounds, Academic Press, London, 1966.

# APPENDIX A

## A SUMMARY OF INTERVIEWS WITH THE MANAGEMENT OF A STATE-OWNED BROMINE PRODUCER IN ISRAEL

### Introduction

The interviewees belong to the following three managerial groups:

Group A - Members of the Board

Group B - Top Executives

Group C - Lower Level Managers

The directors were interviewed separately and each one was asked to describe what he saw as the major corporate objectives of the organization.

The interviewees insisted on informal interviews and consequently the information yielded can give only a general indication of what they regard as the most important objectives. Therefore, the definitions and views given by the directors are qualitative by nature.

It should be noted, however, that quantitative information about the company and its activities was obtained from lower level managers and is presented in Chapter 4, Section 4.9.

For the sake of convenience, the list of corporate objectives seen as important by the interviewees was subdivided into the following categories: National-Economic (NE) Objectives, Social National (SN) Objectives, Social (S) Objectives and Microeconomic (ME) Objectives.

## Results

### The National Economic (NE) Category

Objective:

(i) reduction of the deficit in the national balance of payments.

It was found that members of the board, see (i) as a most important objective whereas top executives attach less importance to it. Lower level managers, however, are not at all concerned with this objective and do not see it as important to them.

### The Social National (SN) Category

Objectives:

(i) contribution to employment in development areas.

(ii) protection of the environment.

Group A considered (i) as the more important objective in this category, arguing that the company should erect new plants in development areas regardless of economic considerations. (ii) is seen mainly as a constraint imposed by legislation.

Groups B and C, on the other hand, attach less importance to (i) since they would commission projects in development areas only on an economic basis, but they attach more importance to (ii) since their aim is to establish environmental standards which are more stringent than those imposed by legislation.

Social (S) Category

Objectives:

(i) job security and job enrichment.

(ii) welfare for families of employees (e.g. education grants for children).

Group A does not see the above as important corporate objectives, whereas groups B and C see these as important ones.

Microeconomic (ME) Category

Objectives:

(i) Increase in bromine and compounds production and sales.

(ii) profitability.

Groups A and B attach more importance to (i) and view (ii) as an important constraint on (i). Both groups see the utilization of the company's full bromine production potential - over 1 million tpa - as the long-term aspiration level for (i). However, the two groups differ in that group B sees (i) as the 'raison d'etre' of the organization for which it was established by the State. Group A, on the other hand, sees (i) under the constraint of (ii) as instrumental to the attainment of higher level national objectives.

In contrast, group C attaches more importance to (ii) and views all other objectives as secondary to it.

Summary and Conclusion

The following table can be constructed to reflect the differing views of the interviewees.

| Management Group / Category and Number of Objective | NE | SN | | S | | ME | |
|---|---|---|---|---|---|---|---|
| | (i) | (i) | (ii) | (i) | (ii) | (i) | (ii) |
| A | (a) | (a) | (c) | (c) | (c) | (b) | (d) |
| B | (b) | (c) | (a) | (b) | (b) | (a) | (d) |
| C | (c) | (c) | (a) | (b) | (b) | (d) | (a) |

(a) - very important objective

(b) - important (instrumental) objective

(c) - unimportant objective

(d) - constraint

The table shows that the groups differ considerably with regard to relative importance of objective. Indeed there is no single category where all agree.

Two factors can explain the noted disagreement:

1. The company does not have any explicit set of objectives and each director is left to interpret for himself, statements of government officials.

2. The different preferences and priorities exhibited by the groups stems from their different positions in the managerial hierarchy. Thus, group A, is more concerned with matters of policy and less with execution and sees more clearly the wider national objectives as the company's objectives.

Group B, on the other hand, has a more specific company mission to attend to i.e. bromine production, hence they see it as the most important one.

Members of group C are judged and evaluated on the basis of the profitability of their action, hence the overriding importance they attach to this objective.

Another finding of the interviews is the unawareness of directors to the conflict, not only between the various objectives (see Chapter 3, figure 9), but also the conflict of views between the groups.

This is again attributed to factors indicating the lack of an explicit set of objectives. Although this situation is not comfortable to all interviewees, (in particular to lower level or middle management, see p. 75), it has its value in (as discussed in Chapter 3, section 3.6.1) avoiding disruptive conflict and keeping the coalition together.

# APPENDIX B

## ENERGY USED IN BROMINE PRODUCTION

| Direct | \$/ton $BR_2$ |
|---|---|
| Steam[1] - 10 tons/t $Br_2$ x \$8/t steam | 96 |
| Electricity[1] - 120 KWH/t $Br_2$ x \$0.05/KWH | 6 |
| Total | 102 |

Indirect (in chlorine)

Chlorine used in the Bromine production:

Chlorine[2] - 0.480 t/t $Br_2$

Energy in chlorine production:[2]

1 ton $Cl_2$ - 3000 KWH

1 ton $Br_2$ = 0.480 x 3000 KWH = 1455 KWH/t $Br_2$

| | |
|---|---|
| Cost 1455 KWH/t x \$0.05/KWH = \$72.2/ton $Br_2$ | 72.7 |
| Total energy costs per ton of bromine | \$174.7 |

Bromine price[3] - bulk \$640/t

Thus energy costs constitute about a third of the market price of bromine.

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1. Private communication from "Dead Sea Bromine"
2. Sherve and Brink, Chemical Process Industries, 4th ed., McGraw-Hill, 1972
3. Chemical Marketing Reporter, October 6, 1981.

# APPENDIX C

## BROMINE AND ASSOCIATED BY-PRODUCT CAUSTIC SODA

## EFFECT ON THE ISRAELI BROMINE PRODUCER

For the Israeli bromine producer, a production objective of more than 1M tons of bromine is associated with approximately 0.5M tons of by-product caustic soda. (It should be noted that the Israeli market is small and most of the caustic soda would have to be exported).

Actually, caustic soda is the by-product of chlorine produced by electrolysis of brine (sodium chloride). Both comprise the well-known and voluminous alkali-chlor industry.[1] (e.g. in 1973 about 12 Mt of chlorine and 13.5 Mt of caustic soda were produced in Europe, similar amounts in North America and lesser quantities elsewhere.[2]).

Since production of 1 ton of chlorine is accompanied by production of 1.13 tons of caustic soda, the demand for the former can affect the latter's market in two directions:

(1) Historically, the world chlorine markets expanded faster than the caustic soda ones. This has resulted in over-supply of caustic soda (see Table 1).

Table 1: Supply demand of Caustic Soda in U.S.

(000 tonnes)

| | 1960 | 1965 | 1970 | 1974 | 1977 | 1979 | 1980 |
|---|---|---|---|---|---|---|---|
| Production | 4511 | 6197 | 9200 | 10150 | 9979 | 11587 | 10260 |
| Demand | 4296 | 5819 | 8294 | 9250 | 9185 | 10406 | 9078 |
| Excess | 215 | 378 | 906 | 900 | 794 | 1181 | 1182 |

Source: A report of Mannsville Chemical Products 1981

(2) Any decline in the demand for chlorine which will cause decreased production may cause a decrease in the availability of caustic soda. Thus, the Mannsville report projects a slow-growth rate of chlorine[3] and higher growth in demand for caustic soda[4] in the 1980s, so that the latter will be in continuous short supply and highly priced to the point that other alkalies would become competitive. However, it should be noted that this appraisal is not supported by Table 2, below:

Table 2

(000 tonnes)

| Product/Year | 1980 | 1981 | 1982 | 1985 |
|---|---|---|---|---|
| Projected demand for chlorine (a) | 10405 | 9697 | 9798 | 11612 |
| Associated caustic soda production (b) | 11758 | 10958 | 11072 | 13122 |
| Projected demand for caustic (c) | 9078 | 9526 | 10342 | 11340 |
| Excesses of caustic soda | 2680 | 1432 | 730 | 1782 |

(a) A report on chlorine - Mannsville Chemical Products 1982

(b) Calculated from (a) using the stoichiometric ratio 1.13

(c) A report on caustic soda - Mannsville Chemical Products 1981

Although Table 2 projects for chlorine a lower annual growth rate (2.2%) between 1980 - 1985, as compared with that of caustic soda (4.55%), it does not show any shortage in caustic soda supply during that period.

For the bromine producer, it is quite obvious that the first case may involve costs of disposal of caustic soda which will adversely affect his overall net returns. But even in the second case, where decline in chlorine production should create shortage in caustic soda supply, the bromine producer cannot always expect to market profitably his excess caustic soda. This is because, as Table 2 demonstrates, a decline in the demand for chlorine is not enough, only its relation to the demand for caustic soda is important in determining excess/shortage of the latter. Moreover, even if a considerable shortage of it results in high prices, competition should be expected not only from other alkalies, but also from non-chlorine based production processes (or caustic soda may become the principal product and chlorine the by-product). In these circumstances, the Israeli bromine producer may be at a cost disadvantage vis-a-vis competition, due to transportation costs and possible duties.

Thus, both scenarios (1) and (2) suggest that large increases in bromine production associated with caustic soda production may pose problems of disposal of the latter.

## References

1. J.J. Leddy et. al. in Kirk-Othmer Encyclopedia of Chemical Technology, 3rd Edition, Vol. 1, 1978, p. 799-865. The authors give a good account on the Chlor-Alkali industry.

2. Ibid. p. 805

3. Chlorine - Chemical Products Synopsis, A Reporting Service of Mannsville Chemical Products, New York, 1982.

4. Caustic Soda - Chemical Products Synopsis, A Reporting Service of Mannsville Chemical Products, New York, 1981.