Technological Innovation Studies Program

Research Report

THE ACQUISITION OF NEW PROCESS TECHNOLOGY BY FIRMS IN THE CANADIAN MINERAL INDUSTRIES

by
Peter R. Richardson

University of Western Ontario

February 1977

Rapport de recherche

Programme des études sur les innovations techniques

Industry, Trade and Commerce
Industrie et Commerce

Technology Branch
Ottawa, Canada

Direction de la technologie
Ottawa, Canada

THE ACQUISITION OF NEW PROCESS TECHNOLOGY BY FIRMS IN THE CANADIAN MINERAL INDUSTRIES

by
Peter R. Richardson
University of Western Ontario

February 1977

The views and opinions expressed in this report are those of the author and are not necessarily endorsed by the Department of Industry, Trade and Commerce.

Table of Contents

		Page
Chapter I	Introduction	8
Chapter II	The Canadian Mineral Industries	23
Chapter III	Literature, Theory and Propositions	51
Chapter IV	Presentation and Discussion of the Research Findings	90
Chapter V	Innovative Strategies of Firms in the Canadian Mineral Industries	112
Chapter VI	Data Presentation and Discussion: Process Equipment Suppliers	129
Chapter VII	Summary and Conclusions	140
Appendix	The Questionnaires	161
Bibliography		189

INTRODUCTION

1.1 PROCESS INNOVATION

The problem of acquiring process innovation in firms is one that has only recently started to attract the attention it deserves. As the world moves through a period of shortages and recession, company executives are paying less attention to new products and more to new processes. They are finding that in times of scarce supply or low demand, process efficiency through innovation can be a more effective competitive weapon than new products. Process efficiency comes about because of process innovation which is very different to obtain, as we are now realising, from product innovation.

In the past, research into process innovation has been dominated by economists who have, quite understandably, sought to explain the development and diffusion of new processes in economic terms. However, in reality, process innovation contains many administrative elements which are at least as important as economic aspects in determining success. Process innovation is made up of several activities which must be integrated; research people must be aware what is happening in development groups and vice-versa. In this respect alone process innovation is more complex than product innovation because these activities can either take place solely in a process-using firm, solely in a specialized process equipment supply firm, or can be shared in some manner between both. Usually all activities related to product innovation take place in a single firm.

Process innovation is more important in some basic industries than in others. In particular there is a class of industries which are mature and in which firms do not compete on the basis of product innovation to any great extent. Important amongst these are the mining, petroleum, electric utility and primary metal industries. In such industries, competitive advantages can be derived by being able to utilise more efficient and lower cost technology than other firms. The Canadian mineral industries, examples of this class, contain firms which compete in international markets on the basis of price. As we will see, the survival of these firms is of substantial importance to the Canadian economy, and the effectiveness with which they acquire new processes will, to a great extent, determine the success of their survival. Consequently it is of interest to know how these firms acquire new process technology.

At the present time, knowledge about the administrative aspects of process innovation is fragmentary, being diffused through many different works. In this book we will attempt to draw this knowledge together with specific application to the Canadian mineral industries. Coupled with the research described later in the book, we will utilise this knowledge to develop an administrative framework for consideration of the general process innovation problem. From the general framework thus developed we will develop a discussion of the imperatives of process innovation for the Canadian mineral industries. In short, the purpose of the book can be described as a study of process innovation in general and the application of the resulting framework to a specific set of Canadian industries.

This book takes a strategic view of process innovation. The two more usual research approaches; studies of groups of specific innovations and studies of particular innovations in a specific firm over a period of time, do not provide the perspective which we are trying to obtain. For our purposes we must view process innovation as a strategic activity which the mining firm can engage in. To carry out effective process innovation requires the long term commitment of resources. These resources must be committed either by the mining firm, or the specialized process equipment supplier. Only by taking this perspective can we view the problem in the same manner as the executive who is interested not in the mechanics of innovation, but rather in the administrative task that must be accomplished in order to be successful. Interviews with senior executives in the mineral industries, on which most of the research in this book is largely based, show that they view process innovation as one of the long-term strategic options in which the firm can engage.

Taking a "strategic view" of process innovation in the research means that we will be not concerned with the specific aspects of particular innovations except as examples to illustrate general points. Rather, the research will be concerned with the major resource commitments that firms make. Budgets for research, development and engineering, number of qualified research and development personnel, and range of innovative activities are all aspects of this resource commitment. Our study covers all these aspects of the innovative activities in mining companies and their specialised suppliers. In the book we will define a set of innovative strategies which these firms can implement. The existence of these strategies was initially postulated from theoretical arguments on innovation and the need for administrative integration between elements of uncertain activities, to which class process innovation belongs. The research demonstrated that each of these strategies exist in Canadian mineral industry firms, and that particular strategies can be associated with particular groups of firms distributed according to size.

The mining executive reading this book could reasonably ask:"which of these strategies is successful?"......"Which is best for my firm?"..... To these questions no definite answer can be given, in part because the terms 'success' and 'best' are very hard to define. However, recognising that practitioners wish to have at least an indication of success, and that in all probability some answer is better than none at all, the book introduces some measures that define success in limited ways. Profitability of the firm depends on too many variables to be attributed to innovative activities, and in general, firms do not regard research, development and engineering as profit centers. So that it is very difficult to measure innovative success through profit. However, a limited measure of success can be obtained from patents and technical licenses held by individual firms. These tangible products of successful innovation exist because the firm feels that a new process or element of a process has a commercial value. For comparative purposes this measure can distinguish firms on a relative basis. A second measure of success (also used by Olsen 1) is that of how firms view each other. In particular, from the point of view of this book, how suppliers view mining firms and vice versa. In this form, the book does contain some measures of success for the innovative strategies described. More importantly, however, each strategy is discussed in terms of its implications for the firm. Consequently executives will be able to ask themselves whether a particular strategy fits the resources, needs and corporate strategy of their own firms.

Researchers interested in the book as a description of existing literature (from the administrative perspective) and of new research will not be interested in limited measures of success, nor the applicability of strategies to particular firms. However, for them the book does contain a description of an important aspect of process innovation; namely the division of innovative activities between user and supplier. When combined with the findings available in existing literature, several issues emerge which have a major impact on our perception of process innovation. For example, there is no doubt that in the infancy of many industries process innovation is initially carried on by using firms themselves. However, as industries grow there is a tendancy to allow specialized suppliers to carry them on. The work of Abernathy (2) has demonstrated that in some cases under these conditions, the rate of innovation declines. Research described in this book shows that in the mature Canadian mineral industries, innovation proceeds at the highest rate in mining firms which integrate the functions of process innovation. Should then all firms wishing to be process innovators integrate the relevant activities and cease to be dependant on specialised suppliers? Such questions, and others, will be discussed in detail at the end of the book.

The remainder of this introduction defines the major concepts about which we are concerned. The words 'process' and 'innovation' mean many things to different people and the intention is to define these and other terms to enable the writer and the reader to agree on the subject matter of the book. Following this section the introduction is concluded by a brief description of the technical problems confronting firms in the Canadian mineral industries. We shall show that these problems are of immediate concern and that within the present industry structure, there is little being done to resolve them.

ChapterII contains a description of the role of the mineral industries in the Canadian economy and shows the magnitude of their contribution. Following this description we will describe the structure of each of the industries with which we are concerned: the ferrous, the non-ferrous and the non-metallic mineral industries. For each of these individual industries we will show the size of firms in the industry, discuss their corporate strategy and consequently show their reliance on process technology.

Chapter III contains a discussion, largely from the administrative standpoint, of the current literature on process innovation. The discussion shows that the economic arguments based on economies of scale are very likely not to hold where innovation is required. Rather, the problems and their effective solution are likely to be administrative in nature and can be fundamentally conceptualised as being a choice between using market or administrative integration to bring about process innovation. From these arguments are developed the propositions which the research was designed to test.

Chapters IV, V, and VI describe the research and present the major findings. In Chapter IV the existence of the individual innovation strategies is proved. Chapter V contains then a discussion of the activities of the firms implementing a particular type of innovative strategy and the magnitude of the resource commitments necessary to sustain these activities. Chapter VI describes in some detail the innovative activities of firms which are process equipment suppliers to the Canadian mineral industries. The research demonstrated that the total effort of these firms is far less than that of even the largest four firms in the mineral industries themselves.

Chapter VII presents a summary of the major findings and the conclusions to the research. There are implications to be drawn about process innovation by executives in private firms, by decision makers in Government and by those interested parties to further research. Individual sections are devoted to the needs of each of these groups. As with other chapters in the book, certain parts of Chapter VII will be of more interest to particular readers than others. In general, those readers concerned with mineral industry problems could omit Chapters III and IV and certain parts of the conclusions, whilst those concerned with research and the general problem of process innovation could omit Chapters II and VI and the appropriate parts of Chapter VII.

1.2 Some Definitions of Concepts Employed

The following definitions of concepts utilised in this book are not meant to be definitive in an absolute sense. Rather they exist to facilitate communication between the author and the reader, (hopefully, when in doubt, readers will refer back to this section). If particular readers object to any of these definitions then they should be careful during further reading to adjust the authors interpretation in terms of their own definition.

1.2.1. <u>Mineral Industry Processes</u>

In the mineral industries, the input to the manufacturing system is ore. The output from the manufacturing system is the refined mineral suitable for use in a variety of applications. The manufacturing process is concerned with the extraction of ore from the ground and its subsequent reduction to a refined mineral. The chain of processes needed to refine crude ore to obtain metals is:

1. Mine the ore.
2. Mill the ore to reduce large chunks into small pieces.
3. Concentrate the ore to increase the mineral content ready for smelting.
4. Smelting to produce 99% pure metal.
5. Refining to produce 99.99% pure metal.

Mine —Ore→ Mill → Concentrate → Smelt → Refine — Metal

Figure 1.1
Mineral Industry Processes

1.2.2. <u>Process Technology</u>

Drucker[3] has characterised the state of technology as "limiting the work we can do." For our purposes this characterisation proves useful. However, two conditions will be added. In this study:

1. The state of technological <u>information</u> limits the development of process technology.
2. The state of process technology limits the work we can do now.

The firm in possession of process technology has distinct advantages over firms possessing only technical information. Before technical information can be turned into process technology, the development and manufacture of process equipment must be undertaken. By this definition, process innovation consists of two major elements: the discovery of a new technique and the physical application of the technique in process equipment. As we will see in the following section, most process innovations in the mineral industries embody both elements.

1.2.3. Innovation

Innovation can be considered to be bringing knowledge, new or otherwise, to commercial application in a novel situation. The process can be considered as a series of stages which for ease of exposition are described serially below. However, the nature of innovation is such that uncertainty ecountered during the stage of development, for example, might necessitate further research. So that in practice, each stage might be present more than once for a particular innovation, and that within a firm research, development and engineering may all be occurring simultaneously on several aspects of the same project or on many different projects.

1.2.4. Research

Research is undertaken to conceptualize and develop specifications for new process equipment. At this stage of the innovation, management's main concern is to establish the viability of a particular process. The research objectives are to determine the particular process configuration that will be successful and to eliminate possible problem areas. No equipment design or material specifications are developed.

1.5.5. Development

Development of the process involves the specification of the equipment dimensions, materials, and design of the working process. This stage may involve the construction of a small scale, prototype operation to investigate the physical characteristics and problems that are to be expected in the operation of the commercial process.

1.5.6. Manufacture

Manufacture of the process involves the assembly and commissioning of the process equipment. Components of the process equipment may be obtained from sources other than the organization responsible for the manufacture of of the equipment. However, characteristicallly, one firm only is responsible for the assembly of the process.

1.5.7. Uncertainty

Knight 4 identified three types of future events, each of which can be characterised by a different type of probability of occurrence. The first type of event is one governed by some physical law that, all things being equal, will enable the accurate a priori prediction of a probable outcome. Such a case is the roll of dice. The second type of event is one of a large class of similar events that have already occurred. The probability of a house burning down belongs to this class of events. For any house a statistical probably of fire within a given time period can be determined from historical records of other fires. The third type of event is one that does not belong to a large class of like events and is not governed by physical laws. Serendipity plays some part in the outcome of these events. Knight characterises these events as follows:

> "The distinction here is that there is no valid basis of any kind for classifying instances." 5

The first two kinds of events can be allowed for by the management of the firm:

> "As we have repeatedly pointed out, an uncertainty which can by any method be reduced to an objective, quantitatively determinate probability, can be reduced to certainty by grouping cases. The business world has evolved several organizational devices for effectuating this consolidation, with the result that when the technique of business organization is fairly developed, measureable uncertainties do not introduce into business any uncertainty whatever." 6

In other words the management of the firm can build an allowance for such events into the cost structure of the firm. However, when accurate calculations based on porbabilities cannot be made, the firm can only move to reduce the unmeasurable uncertainty.

Firms in the mineral industries are faced with unmeasurable uncertainty in two aspects of their operations. These aspects are the discovery of new mineral deposits and the development of new processes to transform ore into refined minerals. The exact location of economic deposits of minerals in the earth is not predictable on any physical or statistical basis. Many mineral deposits are located in areas where they are only found by chance. The successful outcome of process innovation is not something that can be predicted on the basis of past events. Each innovation is a unique occurrence because the result is knowledge not previously existing or applied in a particular way.

1.5.8. Integration

Each stage in the innovation process must be linked to the next stage. Information has to pass between the researchers, the designers and the manufacturer, so as to integrate their activities. These activities may all be in one organization, or they may be in two or more. Functions carried out within the same company are linked administratively. Those functions that are carried on in separate companies are linked through the market mechanism.

1.5.9. Administrative Linkages

The functions of research, development and process manufacture may be linked administratively. These linkages occur within the same firm and are characterised by Wrigley as follows:

> "No contract, price, or specification of performance is necessary for an agreement between individuals or departments. The only contract in effect is the contract of employment between directors of the firm and its employees. All that are necessary in such a contract are the limits of authority and responsibility of the employee. Employee actions are a function of corporate and colleague needs or instructions." 7

1.5.10. Market Mechanism Linkages

For the linking of functions through the market a contract of sale is necessary.

> "The product must be specified in terms sufficient to allow judgement of performance and non-performance. This requires that the buyer know his wants in exact terms. If the buyer

does not know his requirements due to uncertainty the contract may not be binding." 8

Extra goods or services may be supplied by the seller but at extra cost.

1.5.11. Strategy

One purpose of the book is to investigate the selection and implementation of innovative strategies. The definition of strategy that will used is:

A set of decisions committing the resources an organization to moves designed to achieve purpose.

These decisions will determine, among other things, the extent of the commitment of resources within the firm to particular activities, the range of activities that the firm undertakes on a formal basis, and the organization structure of the firm. As the book is concerned with the implementation of strategy, changes in resource allocation, range of activities and structure of the firm will be used to determine changes in strategy.

1.5.12. Structure

The structure of the firm will be considered to be the set of departments into which the firm separates its formal activities. A significant change or increase in the range of activities of the firm will necessitate a change in the structure of the organization to ensure that the new or changed activities are carried out effectively.

1.3 PROBLEMS FACED BY THE MINERAL INDUSTRIES IN CANADA

Uncertainty exists in mining operations due to the unknown locations of recoverable mineral deposits and the mineral content of a deposit once located. Continuity of operations and growth of the firm arise from the discovery of economic ore bodies during exploration activities carried on by the firm. Many mining firms become defunct because they have been unsuccessful in discovering economic ore deposits to replace the depletion of existing ore reserves. Exploration technique are limited. For example, current airborne exploration techniques only permit analysis of rock formations to a depth of 600 feet, and can only indicate the presence of minerals in the earth. The extent and quality of a mineral deposit has to be ascertained through drilling operations which are very costly.

Once a mineral deposit has been discovered, the ore content is one of the major constraints on the economic recovery of the minerals. Canadian mining companies are now faced with the problem of recovering minerals from lower grade mineral deposits than in the past. In 1900 the copper ores being mined in Canada were as high as six percent copper content. By 1950 ores mined contained approximately two percent copper on average, and most recently, in 1974, several porphyry ore bodies with a copper content of 0.5% are being mined.

Mining companies face the risk of developing a mine and being unable to recover minerals economically. Drilling to reveal the extent and quality of the ore provides imperfect information. The decision to mine is taken on the basis of this limited knowledge. In 1972 the Hudson Bay Mining and Smelting Company Limited reported that it was terminating operations at its new $10,000,000 Wellgreen mine in the Yukon. Drilling had failed to outline discontinuities in the ore body that made economic recovery impossible. 9

The decline in the grades of ore bodies is only one of the major technological problems facing the Canadian minerals industries in the coming decade. New ore bodies are being discovered in increasingly remote locations. For example, Cominco Ltd. is currently studying the feasibility of mining lead and zinc on Little Cornwallis Island in the Arctic. 10
The extraction and logistics problems of such operations require the development of sophisticated technology to make the operations economically viable.

There are other technological problems facing the industries. A shortage of manpower in mines is causing cut-backs in production at some operations, and there are needs to make working conditions in mines safer, healthier, and more productive. These needs necessitate the development or adoption within the industries of new technology. Recently the National Advisory Committee on Mining and Metallurgical Research proposed eight major projects that should be undertaken to solve some of the principle national concerns of the mining industry. 11 These are:

1. Application of hydraulic hoisting and ore transport in the mining industry.

2. Steep inclined conveying for ore haulage systems.

3. Primary excavation method in underground metal mines.

4. Improvement in the working environment.
5. Strata control in potash mines.
6. Ground support systems.
7. Development of in-situ methods of recovering synthetic crude oil from the Athabasca tar sands.
8. Development of a high capacity method for mining deep sea nodules.

Recently both government and industry have devoted their attention to the last two problems. The Alberta government has announced its intention to spend $100,000,000 over the next five years into research and development of process technology for the tar sands 12. This action came as a political response to the western oil crisis of 1973-74. Several consortia have been formed to develop methods for mining the deep sea nodules.

The need for new process technologies in the Canadian mineral industries is not new, but has been the subject of discussion for a number of years. Writing as early as 1967, Dr. A.J.R. Smith, Chairman of the Economic Council of Canada stated: 13

> "In the twentieth century, we have successfully built a strong minerals sector in the Canadian economy... a continuation of the strong growth in Canada's mineral industries will necessarily depend on holding down costs and remaining highly competitive.
>
> Productivity improvement should therefore be a matter of very high priority. It will require effective progress on many fronts:
>
> - better long range planning relating to all basic aspects of business decisions - investment and technological change, manpower and marketing;
>
> . . .
>
> - the development and application of new knowledge and technology in exploration and discovery, in the extraction of minerals from the earth and in the transformation of raw products into

industrial materials."

In a similar vein, A. E. Boone, Director, Product Planning, Joy Manufacturing, writing in 1970 observed:

> "The mineral industry (in Canada) must grow, but the rate of growth will depend on the research and development of greatly improved techniques and equipment, and the adequate education and training of sufficient numbers of people to efficiently achieve growth objectives." 14

Clearly, there is a need in the Canadian mineral industries for new process technology. However, the aquisition of this new technology requires that management provide the necessary resources for innovation to take place. If management does not provide strong support for research, development and process manufacture, then it is possible that the required process innovations will not occur. J. W. Reynolds, an employee of Cominco working in research and development states:

> ". . . research and development presents industry. . . with policy problems. Items such as fires, floods, ore reserves, unions, shareholders and governments are factors in 'getting by' and 'making a profit' but fresh ideas fall into a somewhat different category. Anything constituting a change must overcome the inertia of accepted practice. New concepts necessarily involve unknown quantities, challenges of known limits, or accepted practices and, not infrequently, risk to capital . . . . Consequently, an industry such as mining which tends to be bound by these attitudes and by related factors such as expensive capitalization, long term planning, arduous working conditions, and public misunderstanding, requires an aggressive policy in support of research if resistance to change is to be overcome. Without strong policy support, research cannot exist in a mining environment." 15

From this view, one of the major factors inhibiting process innovation in firms in the mineral industries may be a lack of management support for resource allocations by the firm to innovative activities. It may be that managers in some firms in the mineral industries do not perceive process innovation as sufficiently important to warrant resource commitments. However, managers in other firms in the mineral industries may be committing large amounts of resources to the acquisition of process innovation. No research has yet established which firms in the Canadian mineral industries carry out process innovation or how they acquire process innovations. No satisfactory model exists which explains what innovative strategies can be employed by mining firms. The research described in this book will remedy these deficiencies and will propose a model showing what alternative strategies may be implemented.

References For Chapter I

1. Olsen, R. P., Sources of Process Innovation in the Textile Industry: Unpublished Doctoral Dissertation; Cambridge, Mass., Graduate School of Business Administration, Harvard University, 1974.

2. Abernathy, W. J., "Policy Issues in Technology and Process Development: The Evolution of U.S. Automotive Engine Plants." Working Paper 75-76, Graduate School of Business Administration, Harvard University, Boston, Mass., 1975.

3. Drucker, P. F., Technology, Management and Society: New York, Harper and Row Inc., 1970.

4. Knight, F., Risk, Uncertainty and Profit: Reprinted, New York, Harper and Row, Publishers, Inc., 1965.

5. Knight, F., ibid.

6. Knight, F., ibid.

7. Wrigley, L., R/D and Production: Model Predicting Relationship in Various Economic States, unpublished paper: School of Business Administration, The University of Western Ontario, 1973.

8. Wrigley, L., ibid., pp. 3-4.

9. Hudson Bay Mining and Smelting Company Ltd., Annual Report, Toronto, 1973.

10. Cominco Ltd., Annual Report. Vancouver, 1973.

11. Report of the Mining Sub-Committee, The National Advisory Committee on Mining and Metallurgical Research, Ottawa, 1973.

12. Article in The Globe and Mail, Toronto, November 12, 1973.

13. Smith, A.J.R., "Productivity Growth and Canada's Mineral Industries," The Canadian Mining and Metallurgical Bulletin: Montreal, February, 1968.

14. Boone, A. E., "Canadian Mining in the Seventies," The Canadian Mining and Metallurgical Bulletin: Montreal, August, 1970.

15. Reynolds, J. W., "Research and Technical Development in a Mining Operation," The Canadian Mining and Metallurgical Bulletin: Montreal, April, 1970.

CHAPTER II

2.1. Introduction

The Canadian economy has been characterised as a staples economy by some economists. Amongst these, Watkins has suggested that the basic assumption is that the staple exports are the stimulii for economic growth:

> "The fundamental assumption of the staple theory is that staple exports are the leading sector of the economy and set the pace for economic growth." 1

The mineral industries have been one of the foremost amongst those which have been the stimulus of Canada's economic growth during the last century. Alongside agriculture, forestry and fishing, they have been critical catalysts in the development of transport systems, communities and secondary industries. However, it is necessary for our argument to stress that they continue to play a key role in the Canadian economy, this we will do in the first part of the chapter.

Having examined briefly the role of the mineral industries in the economy, the second part of this chapter will consider in turn each of the three mineral industries with which we are concerned. Although for some purposes the mineral industries may be considered as a homogeneous group, this will not be possible in this book until the need for new processes has been shown to be common to each of these industries. The three industries are:

1. The ferrous mineral industry.
2. The non-ferrous mineral industry.
3. The non-metallic mineral industry.

Firms in each of these industries will be shown to have different strategies for survival and growth. However, within these strategies the ongoing need for new process technology will be shown to be a common element.

The way in which these firms act on the need for new technology may depend to some extent on their size and the resources they can commit to innovation. Hence, for each industry, a classification of firms into three size groups will be made. This classification will be used in the final chapter to enable the research results obtained from a sample of these firms to be discussed in relation to the total population.

For each industry considered here, aggregate factor productivity data will be used to give some indication of the rate of technological change. The structure of each industry will then be described in some detail, followed by a discussion of the strategies employed by the firms in the industry. From this discussion will be developed an analysis of the relationship between corporate strategy and the need for new technology. The chapter will be concluded by a summary of the findings on technological need and a classification of firms by size for all three mineral industries.

2.2. The Mineral Industries in the Canadian Economy

Canada has always been a net importer of secondary manufactured goods. In exchange for these items, Canadian industries have exported staples such as farm produce, fish, lumber and minerals. Table 2.1 shows the percentage of Canadian exports for selected years 1954-1973 that belongs to different commodity classes. These figures show that in total, the percentage of exports attributable to the primary resource industries apparently declined from 1954 onwards, falling from 89% of the total in 1954 to 61% in 1973. However, of this total, the.........................

TABLE 2.1

CANADA'S DOMESTIC EXPORTS BY MAJOR COMMODITY GROUPS AS PERCENTAGE OF TOTAL EXPORTS

SELECTED YEARS

Commodity Group	1954-56	1963-65	1968	1972	1973*
<u>Farm and Fish Products</u>					
Wheat and wheat flour	11.2	12.3	5.6	4.9	4.9
Barley oats and rye	2.7	0.8	3.9	1.2	1.0
Other farm and fish	9.4	8.4	5.9	5.8	6.7
	23.3	21.5	15.4	11.9	12.6
<u>Forest Products</u>					
Lumber and other	11.4	5.7	7.4	8.4	9.1
Woodpulp	6.7	5.8	4.7	4.2	4.2
Newsprint	15.6	13.8	7.5	6.0	5.5
	33.7	25.3	19.6	18.6	18.8
<u>Mineral Products</u>	31.9	35.1	32.3	28.3	29.7
<u>Total Primary Resource</u>	88.9	81.9	67.3	58.8	61.1
<u>Cars, trucks, etc.</u>			20.5	24.2	22.2
<u>Aircraft</u>	11.1	18.1	2.8	2.4	1.8
<u>Other</u>			13.0	14.5	14.5
<u>Total Value</u> (millions of dollars)			13,270	19,500	17,422

Source: 1954-56, 1963-65, B. W. Wilkinson, *Canada's International Trade*, pg. 34, Table 13, Reference *Bank of Canada, Statistical Summary Supplement*, 1965.
1968, 1972, 1973, *Bank of Canada, Economic Review*, January, 1974.

*3 Quarters only.

percentage due to mineral production has remained steady at approximately 30%. If the imports of commodities for this period are examined in a similar manner (see Table 2.2) it is apparent that the resource industries are still the key contributors to a favourable balance of trade position. The growth in exports of manufactured goods has been matched by a corresponding increase in imports. The foreign currency earnings from the resource industries continue to provide the necessary funds to purchase consumer and producer goods from abroad. During this period the mineral industries appear to have become more important than either the forestry or the agriculture industries as generators of foreign earnings from resource exports.

Capital formation by the mineral industries is a large and continuing market for other businesses in Canada. Table 2.3 shows the amount spent by the industries for selected years 1954 to 1970 on capital and repair expenditures for plant and equipment. Being capital intensive, the mineral industries are not major employers of labour as compared to some other industries, although there is good reason to suppose that they do generate substantial employment in many other sectors of the economy. The mineral industries employ directly about four percent of the total Canadian labour force. This figure does not include the indirect employment generated in secondary processing and fabricating industries, service industries, and mining communities. Some evidence of the magnitude of the indirect effect can be obtained from the Thompson, Manitoba nickel project undertaken by Inco 2. Employed directly at the mine are approximately 3,600 people, while in the town of Thompson, which exists solely because of the mine, the total population is approximately 20,000.

TABLE 2.2

IMPORTS OF MAJOR COMMODITY GROUPS AS
A PERCENTAGE OF TOTAL IMPORTS

SELECTED YEARS, 1953-1973

Product Group	1953	1965	1968	1972	1973*
Primary Farm, textiles, fur and leather			5.1	5.2	5.7
Fuels and Lubricants	11.8	7.2	6.6	6.0	5.1
Ores, primary metals and minerals			6.7	5.8	5.6
Chemicals			11.0	10.7	10.7
Producer's Equipment			22.0	22.2	22.4
Motor Vehicles and Accessories	6.9	12.3	31.1	31.0	31.5
Consumer Goods (inc. food)	21.8	22.5	17.3	19.1	19.0
Total Value (millions of dollars)		———	12,083	18,443	17,727

Source: 1953, 1965, B. W. Wilkinson, *Canada's International Trade*, pg. 176, Table A-7. Reference *Bank of Canada, Statistical Summary Supplement*, 1965, 1968, 1972, 1973, *Bank of Canada, Economic Review*, January, 1974.

*3 Quarters only.

TABLE 2.3

CAPITAL AND REPAIR EXPENDITURES, MINERAL INDUSTRY
SELECTED YEARS, 1951-1970
('000,000's)

Year	CAPITAL EXPENDITURES Construction	Machinery	Sub Total	REPAIR EXPENDITURES Construction	Machinery	Sub Total	Total
1951	204	195	399	44	156	200	599
1955	435	237	672	59	205	264	936
1961	434	217	652	76	276	352	1,004
1965	721	428	1,149	106	459	565	1,714
1968	978	545	1,523	189	489	778	2,301
1970	1,171	790	1,960	223	640	863	2,823

Source: Capital and Repair Expenditures in the Mineral Industry, Mineral Economics Research Division, Department of Energy Mines and Resources, Ottawa, 1972.

The economic impact on Canada of a major recession in the mineral industries may be very serious. Much of the wealth of the nation stems from the products of this sector. Table 2.4 shows the relationship of mineral production to Gross National Product for selected years 1945-1970.

These figures show that the mineral industries made a significant contribution to G.N.P., but that the economy is apparently not dependent on the industries to any great extent.

However, Table 2.5 shows the proportion of total mineral production that is exported. Clearly, if the mineral products from Canada were to become noncompetitive on world markets, the country would suffer a serious dislocation in its balance of trade. This dislocation could ultimately cause serious shortages of imported goods in Canada, resulting in imbalances in the economy that could have serious implications for the quality of life in Canada.

TABLE 2.4

MINERAL PRODUCTION RELATED TO GROSS NATIONAL PRODUCT

SELECTED YEARS, 1945-1970

('000,000's)

Year	Mineral Production	Gross National Product (G.N.P.)	Mineral Production as per cent of G.N.P.
1945	499	11,863	4.2
1950	1,045	17,955	5.8
1955	1,795	27,895	6.4
1960	2,493	37,775	6.6
1965	3,745	54,897	6.9
1970p	5,769	84,468	6.8

Source: Dominion Bureau of Statistics Data.
p: Preliminary.

We have shown that the mineral industries in Canada have been and still are an important sector of the economy and that their growth in the past is a principal reason for the status and wealth that the country currently experiences. In the future, Canadian mineral industries could find competition increasingly difficult in world market due to the technological problems they face that mineral industries in other countries do not. If the mining companies that form the

TABLE 2.5

EXPORTS OF PRINCIPAL MINERALS. IN RELATION TO PRODUCTION, 1970p

	Unit	Production	Exports	Export as a per cent of Production
Copper	s.t.	673,748	471,522	70.0
Iron Ore	l.t.	47,508,750	21,250,969	44.7
Lead	s.t.	383,208	318,734	83.2
Nickel	s.t.	308,040	293,757	95.4
Silver	troy oz.	44,282,680	45,227,504	102.1
Uranium, U_3O_8	lb.	8,021,000	4,200,000[e]	52.4
Zinc	s.t.	1,211,298	1,197,445	98.9
Asbestos	s.t.	1,654,000	1,562,432	94.5
Gypsum	s.t.	6,442,000	4,853,304	75.3
Elemental sulphur	s.t.	3,779,850	2,988,432	79.1
Coal	s.t.	16,047,000	4,391,575	27.4
Crude oil	bbl.	455,382,000	240,693,633	52.9
Natural gas	Mcf.	2,295,278,000	768,112,547	33.4
Molybdenum, Mo content	lb.	35,353,500	30,334,000	85.8
Potash, K_2O	s.t.	3,424,000	2,504,000[c]	73.1

Source: Statistics Section, Mineral Resources Branch, Department of Energy, Mines and Resources.

p: Preliminary

e: Estimated

mineral industries do not develop and maintain a technological capability that enables them to survive and grow in the future, then there could arise a situation in which these companies can no longer compete in world markets, threatening not only their survival, but the economic welfare of the country. This problem has already arisen in the gold mining sector, although it was too small in impact to seriously affect Canada's international position. Between 1960 and 1971 when gold was selling for $35 per ounce, Canadian gold mines did not have technology that would economically allow them to mine the low grade ore deposits which are relatively common in certain areas of Canada. If this situation were to arise in other sectors, and Canadian mines were not able to extract ore economically, the impact on Canadian industry and on the economic welfare of the country could, in the long run, be enormous.

2.3. THE FERROUS MINERAL INDUSTRY

The ferrous mineral industry in Canada is a relatively recent development. Substantial iron mining in Canada was first undertaken during the post World War II period. In 1965 the total value of production for the industry was $358,393,000. In 1973 the value of production was $613,000,000, an increase of 75% over 1965, and accounting for approximately fourteen percent of the value of production for all mineral industries in this research.

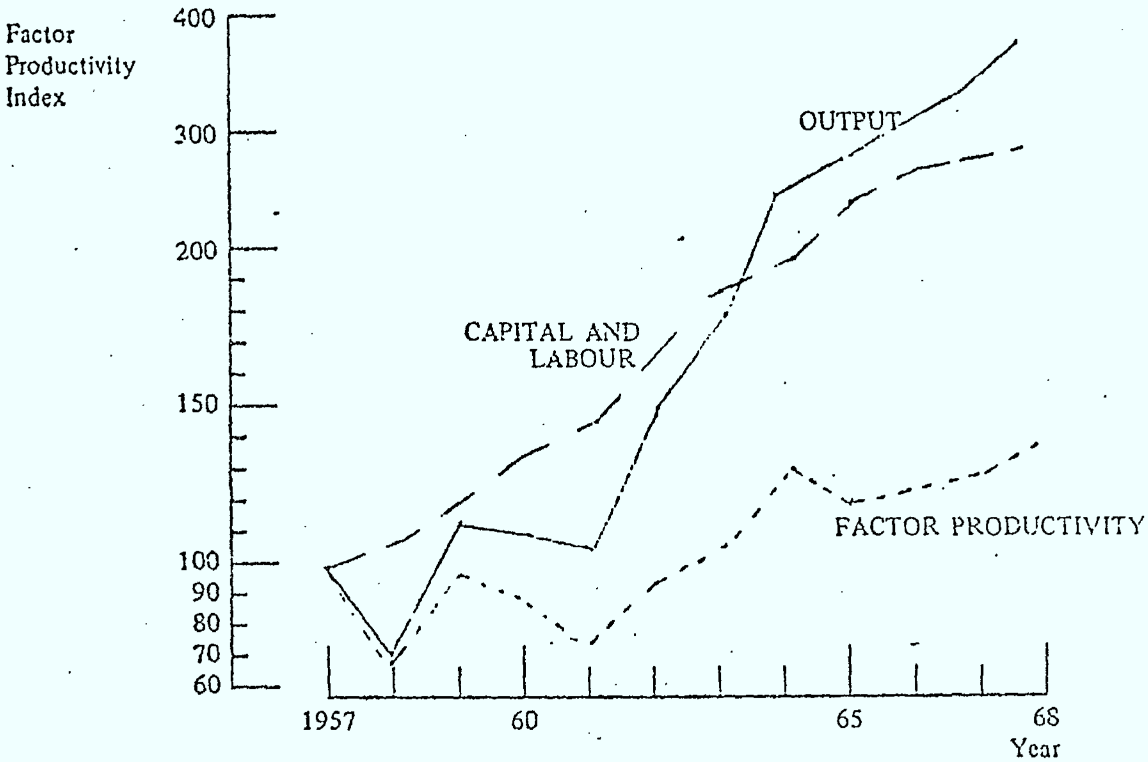
Between 1960 and 1965 capacity in the ferrous mineral industry increased rapidly. As can be seen in Figure 2.1., this increase was accompanied by a sharp rise in factor productivity. Since 1965 the rate of growth of capacity, and of factor productivity has declined from the levels of previous years.

Few published data are available for operating statistics in Canadian iron mining. Clearly, as shown in Table 2.6 the formation of an iron mining company generally represents a vertical integration venture by one or more steel producers to secure sources of supply. There is only one major independent mine operating in the Canadian ferrous mineral industry. The infrastructure necessary to support the operations of an iron mine is extremely complex. Construction of power facilities, transportation facilities for the large volume of product, shelter for workers, and expensive production plant is necessary. However, beyond these necessary activities, mining companies in the ferrous mineral industry have not attempted to diversify. They exist

FIGURE 2.1

CHANGES IN OUTPUT, COMBINED CAPITAL AND LABOUR INPUTS, AND FACTOR PRODUCTIVITY IN IRON MINING

(1957 = 100)



Source: Dawson, J., Productivity Change in the Canadian Mining Industries. Staff Study No. 30, Economic Council of Canada, 1971.

TABLE 2.6

PRINCIPAL IRON MINING COMPANIES AND MAJOR SHAREHOLDERS

Name of Company	Shareholders
Iron Ore Company of Canada	Labrador Mining and Exploration Co.: 4.5% Holinger Mines Ltd.: 10.0% Hanna Steel Corp.: 25% Bethlehem Steel Corp.: 19% National Steel Corp.: 17.5% Armco Steel Corp.: 6% Republic Steel Corp.: 6% Youngstown Steel Corp.: 6% Wheeling – Pittsburgh Steel Corp.: 6%
Quebec Cartier Mining Co.	United States Steel Corp.: 100%
Quebec Iron and Titanium Co.	Kennecott Copper Corp.: 66.66% New Jersey Zinc Corp.: 33.33%
Algoma Ore Division	Algoma Steel Ltd.: 100%
Marmoraton Mining Co.	Division of Bethlehem Steel Co.
Caland Ore Co.	Inland Steel: 100%
Griffith Mine	Leased to Steel Co. of Canada until Aug. 20, 2040
Sherman Mine	Dominion Foundries and Steel Co.: 90%
Steep Rock Iron Mines Ltd.	Independent. Joint venture operation with Algoma Steel Ltd.
National Steel Co. of Canada	National Steel Corp.: 100%
Adams Mine	Dominion Foundries and Steel Co.: 100%
Texada Ltd.	Kaiser Aluminium and Chemical Corp.: 100%
Westfrob Mines Ltd.	Falconbridge Nickel: 100%
Hilton Mine	Steel Company of Canada: 50% Jones and Lauchlin: 25% Pickards and Mather: 25%
Wabush Mine	Steel Company of Canada: 25.6% Dominion Foundries and Steel: 16.4% Youngstown Steel Corp. Interlake Steel Corp. Wheeling Pittsburgh Steel Corp.

Source: Financial Post Survey of Mines, 1972.

TABLE 2.7

PRINCIPAL IRON MINING COMPANIES AND PRODUCTION CAPACITIES

Name of Operation	Tonnage Per Year	Per Cent of Industry Total Capacity
** Iron Ore Company of Canada	33,000,000	53.0
Quebec Cartier Mining Co.	8,000,000	13.0
Quebec Iron and Titanium Co.	637,000	1.0
Algoma Ore Division	2,000,000	3.0
Marmoraton Mining Co.	500,000	1.0
Caland Ore Co.	2,300,000	4.0
Griffith Mine	1,500,000	2.5
Sherman Mine	1,000,000	1.5
Steep Rock Iron Mines Ltd.	1,400,000	2.5
National Steel Co. of Canada	680,000	1.0
Adams Mine	1,100,000	2.0
Texada Ltd.	550,000	1.0
Westfrob Mines	1,100,000	2.0
Hilton Mine	900,000	1.5
Wabush Mines Ltd.	6,000,000	9.5
* International Nickel Co.	900,000	1.5
* Falconbridge Nickel Mines	300,000	0.5
* Cominco Ltd.	200,000	0.3

Source: Financial Post Survey of Mines, 1972.

**Production Capacity Increases due on stream 1973.

*By-product of non-ferrous mining operation.

to act as a source of supply for the steel complexes that own them. Being such sources, their future depends on their ability to remain low cost suppliers of iron ore.

Most of the iron mines in Canada are large open pit operations. They represent a politically and, at the present time, economically stable source of supply for the Canadian and United States steel industries. However, iron ore is not a scarce resource. Total proven world reserves are sufficient for at least 100 years 3, and there are large, high grade deposits known in Brazil, Australia and several other countries. However, the cost of transport for iron ore is relatively high in relation to its value, and therefore Canadian deposits currently represent a convenient source of supply for both domestic and eastern United States steel mills. The future of these Canadian operations depends on their ability to remain low cost suppliers compared to the alternative sources. To accomplish this cost control, factor productivity can be seen as a critical element in the competitive strategy of these iron mines. Increasing factor productivity can only arise from a flow of new, cost saving, process innovations.

There are fifteen operating iron mines in Canada. The annual production tonnages of each of these mines is shown in Table 2.7. At an average price of $12 per ton 4, the mineral revenues for the largest company, the Iron Ore Company of Canada may be estimated at $240,000,000 while those of the smallest, Marmoraton Mining Company are estimated to be $6,000,000 in 1974. Using $12 per ton as an average price, the mineral revenues of the iron mines can be estimated and classified as shown in Table 2.8.

TABLE 2.8

MINERAL REVENUES OF IRON MINES IN CANADA

Range of Mineral Revenues*	Number of Firms
$ 00 to $ 40,000,000	11
$40,000,000 to $100,000,000	2
Over $100,000,000	2

*Assumes iron ore at $12 per ton.

2.4. THE NON-FERROUS MINERAL INDUSTRY

The non-ferrous mineral industry is the largest mineral industry in Canada, representing over seventy percent of the value of mineral production for the industries in this research. The value of production for the non-ferrous mineral industry in 1973 was $3,180,000,000, an increase of 120% over the $1,414,209,000 reported in 1965.

Classified as products of the non-ferrous mineral industry are copper, zinc, silver, lead, nickel, molybdenum, gold and uranium. Canada is the largest producer in the western world of nickel and zinc, second largest of lead and fourth of copper. 5

Dawson[6] separated productivity data for the non-ferrous mineral industry into two groups, gold mines and miscellaneous metal mining. In the miscellaneous metal mines he found little growth in factor productivity during the period 1957-67. His comments follow below:

> "In only . . . copper - gold - silver mines was there a steady increase in production. . . . Even with the substantial increases in production, gains in output per man-hour were only modest, amounting to no more than 2 per cent per annum over the period. Had it been possible to take into account the increases in capital invested, it is likely that one would have found no increases in factor productivity.
>
> . . . . . .
>
> ". . . silver - lead - zinc mines . . . shift in this industry to capital intensive types of mining, and the large increases in capital involved . . . it is unlikely however that there was any increase in factor productivity." 7

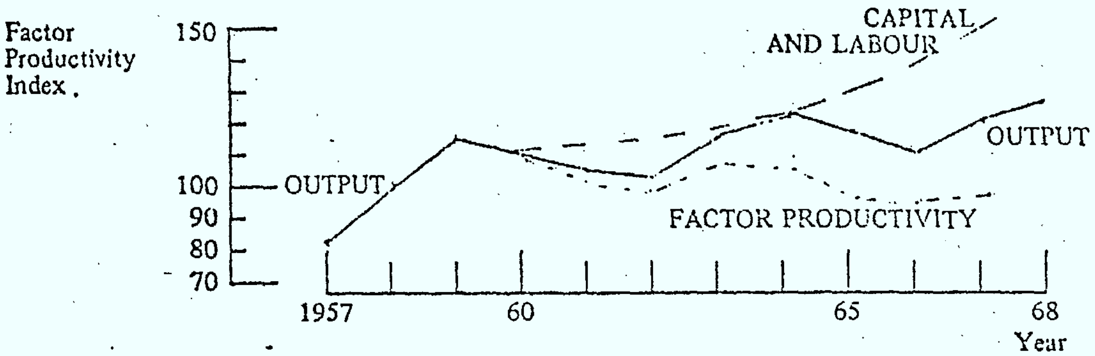
Figure 2.2 shows graphically the changes in output and factor productivity estimated by Dawson for the period 1957-1968.

A federal Government of Canada survey of the non-ferrous

FIGURE 2.2

CHANGES IN OUTPUT, COMBINED CAPITAL AND LABOUR INPUTS,* AND FACTOR PRODUCTIVITY IN MISCELLANEOUS METAL MINING

(1961 = 100)



Source: Dawson, J., Productivity Change in the Canadian Mining Industries. Staff Study No. 30, Economic Council of Canada, 1971.

*Data on labour inputs are not available for years other than 1961-67.

TABLE 2.7

AVERAGE SIZE OF NON-FERROUS MINERAL FIRMS, 1970
($000,000's)

	Mine	Mine, Smelting and Refining
Number of Firms	123	9
Assets	12.3	363
Equity	8.4	236
Sales	6.1	186
Profit	1.9	57

Source: Corporations and Labour Unions Returns Act, Ottawa, Statistics Canada, 1973.

mineral industry carried out in 1970 identified 132 firms as being active.[8] Of these firms, nine were integrated firms with activities in mining, smelting and refining. As can be seen in Table 2.9 the mean assets, equity, sales and profits for these integrated firms are far larger than for non-integrated firms.

In 1973 sales and profit after taxes are shown for each of the nine integrated producers in Table 2.10. Two of these integrated producers, Gaspe Copper Mines Ltd. and Brunswick Mining and Smelting Company Ltd. are

TABLE ~~2.5~~ 2.10

SALES AND PROFITS OF INTEGRATED NON-FERROUS COMPANIES, 1973

Company	($000,000's) Sales	Profits
International Nickel Company Ltd.	1,172,000	468,430
Noranda Mines Ltd.*	849,000	121,000
Cominco Ltd.	513,986	42,835
Falconbridge Nickel Ltd.	438,163	47,904
Hudson Bay Mining and Smelting Ltd.	180,998	47,288
Sherrit Gordon Ltd.	124,092	20,986
Brunswick Mining and Smelting Ltd.	78,956	9,859
Gaspe Copper Mines Ltd.	48,467	1,195
Texasgulf Inc.**	n.a.	n.a.

Source: Corporate Annual Reports.

*Includes substantial revenues and earnings from non-mineral operations.
**Incorporated in U.S.A.

subsidiaries of Noranda Mines Ltd. The seven other integrated producers, with the exception of Texasgulf Inc. are all long established mining companies which were established to work a major ore body. For example: Noranda Mines Ltd. was founded to develop the Horne deposit at Noranda; Hudson Bay mining and Smelting and Flin-Flon copper-zinc deposits; and

The International Nickel Company the nickel deposits around Sudbury.

The growth of these integrated producers has been derived from the stream of funds generated by the rich ore bodies mentioned previously. Each company has implemented a different corporate strategy from its competitors.

For example, Noranda has concentrated on forward integration and diversification. In 1973, approximately half the total revenues of this company were from non-mining operations. Rather than carry out its own major exploration programmes, Noranda has adopted a strategy of providing technical and financial resources for the development of ore bodies discovered by others in return for equity in a joint mining venture. The International Nickel Company, until 1974, followed a strategy of non-diversification. Instead the company concentrated on the processing of nickel and copper:

> "It appears to have done just fine with an old-fashioned management that stuck to nickel and copper mining." 9

Until 1962 the strategy of the Hudson Bay Mining and Smelting Company was to carry out its own exploration programmes in Manitoba and Saskatchewan. Management of the firm hoped to discover mineral deposits that would yield high grade sulphide ores for treatment at the company's smelter in Flin-Flon. In 1962 effective control of the company was obtained by Anglo American Corporation of South Africa Ltd. Soon after his acquisition the company started to diversify into secondary manufacturing and other resource industries. 10

Successful growth strategies of major integrated mining companies appear to contain two major elements. The first is a process of forward integration to develop captive fabrication markets for mineral products. The second is a strategy by which a stream of new ore reserves are acquired, either through in-house exploration or through purchase. In contrast to this strategy, small, one mine companies never develop the output to justify integration forward into smelting or refining. The products of these mines, in concentrate, or crushed ore form, are shipped to the smelting complexes of the integrated producers for smelting and refining.

However, some small firms do grow and survive. These smaller firms do so by re-investing earnings in exploration and in the shares of large dividend paying companies. Survival is perceived by the management of these firms in the context of the discovery of a new ore body. Consequently, earnings are re-invested in exploration. However, when earnings exceed exploration requirements, the surplus is re-invested to provide cash flow in periods of low income.

The general need for new process technology in these mining firms is illustrated by the particular problems facing Inco:

> ". . . . . . The company is having to dig deeper, at greater expense to find workable grades of nickel ore. . . . But forty years ago, when Inco was mining near the surface at relatively low cost, every ton of ore extracted yielded sixty pounds of nickel; today Inco is mining ore with less than half that nickel content." 11

The declining ore grades and availability of deposits in Canada mean that firms in the non-ferrous mineral industry must develop new process technology to improve factor productivity and remain competitive in world markets.

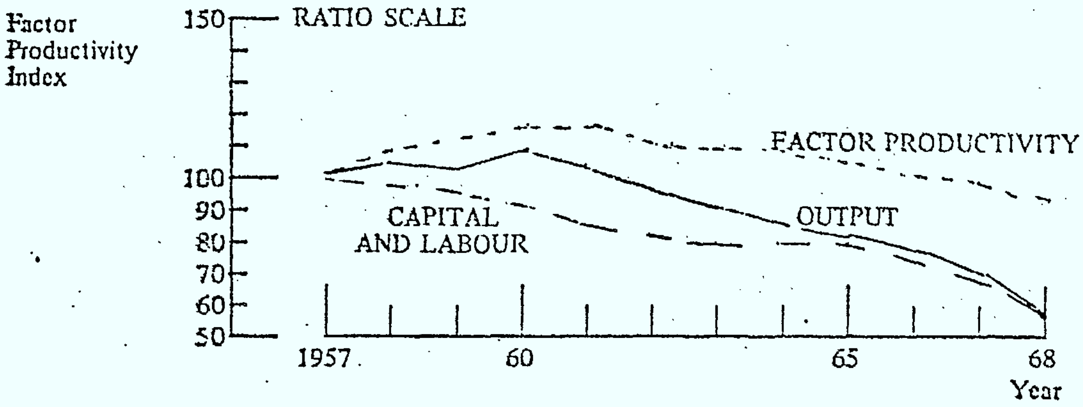
The gold mining industry in Canada provides an example of the outcome of stagnation in factor productivity. Figure 2.3 shows the decline in output for the Canadian gold industry from 1960 to 1968. During this period the world price for gold remained between $35 and $44 an ounce. The labour intensive gold mines in South Africa, having a large supply of cheap labour, were able to sell gold at these prices and remain profitable. In Canada, however, the cost of labour increased during the period and little change occurred in factor productivity. The result was a dramatic decline in the output of gold and in the number of mines operating. Table 2.11 shows that between 1964 and 1971 the number of gold mines and the value of gold production both declined by approximately 50%.

Lode or quartz gold occurs in Canada in deposits that are characterised by narrow veins of ore, often less than four feet wide. Most

FIGURE 2.3

CHANGES IN OUTPUT, COMBINED CAPITAL AND LABOUR INPUTS, AND FACTOR PRODUCTIVITY IN GOLD MINING

(1967 = 100)



Source: Dawson, J., Productivity Change in Canadian Mining Industries, Staff Study No. 30, Economic Council of Canada, 1971.

gold mining operations have been labour intensive and in the past there has been little attempt by the management of gold mines to replace human labour with machinery. The response of the management of gold mines to low prices and high costs was to cut back production and lobby the Government of Canada for emergency

TABLE ~~2.6~~ 2-11

NUMBER OF ESTABLISHMENTS AND OUTPUT, GOLD MINING, SELECTED YEARS, 1964-1971

Year	Gold Quartz Mines	Gold Production (Ounces)	Production Value ($000's)
1964	49	3,210,105	104,204
1966	54	2,719,750	95,751
1968	42	2,217,748	78,908
1970	30	1,891,123	64,190
1971	26	1,753,000	59,698

Source: Statistics Canada Catalogue.

assistance. Government assistance was provided under the provisions of the

Emergency Gold Mining Act. In 1971 all mines with the exception of two, which were ineligible, sold all or part of their production to the Royal Canadian Mint and received assistance payments in excess of the world price for these ounces.

Since 1971 the price of gold on world markets has risen dramatically. The price rose from $37.87 (U.S.) in January 1971 to $200.00 in December 1974. As a result the industry in Canada has been revived and new mines are being brought into production. The change in the fortunes of the gold mining industry is illustrated by the comparative earnings for 1971 and 1973 of the Dome Mines group of companies shown in Table 2.12.

Without the rise in the world price of gold it is unlikely that firms in the gold mining industry in Canada would have been able to halt the decline

TABLE 2.12

GOLD SALES OF THE DOME MINES GROUP

	Sales 1971	Sales 1973
Dome Mines	$ 17,589,000	$ 43,508,128
Campbell Red Lake Mines	$ 8,245,000	$ 19,870,000
Sigma Mines Quebec	$ 3,306,000	$ 8,131,000

Source: Annual Reports for Dome Mines Ltd., 1972 and 1974.

in their output and population. Dramatic price shifts, such as the one occurring in the gold mining industry are unlikely to take place for other non-ferrous mineral industries. One way that firms in these industries will be able to remain competitive is by increasing factor productivity through the acquisition of new process technology.

The total number of firms active in the non-ferrous mineral industry in Canada is provided in a recent publication of the Mining Association of Canada. These data indicate a total of 124 active firms in the non-ferrous mineral industry in 1973. This number is eight less than was shown in the previous Government of Canada study 12. Published income statements are not available for all these mines, as some are subsidiaries of foreign corporations. However, analysis of those income statements that are available and data provided in the Financial Post Survey of Mines for 1973 has been grouped according to mineral revenues in Table 2.13.

TABLE 2.8 13

MINERAL REVENUES OF FIRMS IN THE NON-FERROUS MINERAL INDUSTRY IN CANADA

Range of Mineral Revenues	Number of Firms
$ 00 to $ 40,000,000	95
$40,000,000 to $100,000,000	20
Over $100,000,000	9

2.5. THE NON-METALLIC MINERAL INDUSTRY

In this section we will be concerned with two minerals, asbestos and potash. Between them, these two minerals accounted for 75% of the production of the non-metallic mineral industry in 1971. The value of this production was $454,259,000.

The production of potash and asbestos in large quantities is a recent development in the Canadian mineral industries. Output of these non-metallic minerals has doubled since 1960, but factor productivity, which increased steadily between 1958 and 1965, declined sharply after 1965. These data are shown in Figure 2.4.

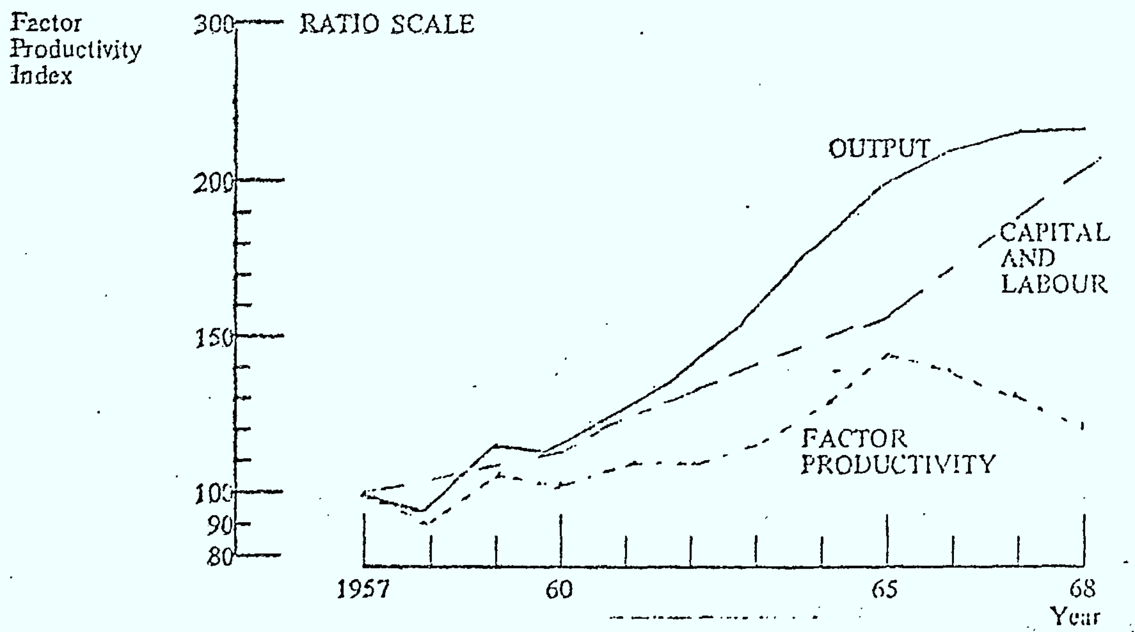
The value of asbestos production in Canada in 1971 was $210,435,000, an increase of 1% from the previous year. Canadian production accounted for

$43.5% of total world production in that year. The Canadian output was derived from twelve producers operating fourteen mines. Sixty three percent of all production was accounted for by two producers, Asbestos Corporation and the Canadian Johns Manville Company Ltd. Operating data on the major asbestos producers is presented below in Table 2.14.

FIGURE 2.4

CHANGES IN OUTPUT, COMBINED CAPITAL AND LABOUR INPUTS, AND FACTOR PRODUCTIVITY IN NON-METAL MINING

(1957 = 100)



Source: Dawson, J., Productivity Change in Canadian Mining Industries, Staff Study No. 30. The Economic Council of Canada, 1971.

*Excludes structural materials and services incidental to mining.

There is little forward integration or diversification by asbestos mining companies in Canada. Asbestos fibre is shipped in its raw state to fabrication operations in the United States and Europe. There is some argument that Canadian consumption (2.8% of total world consumption in 1971) is not large enough to support economic scale asbestos fabrication operations.

TABLE 2.9 2.14

MAJOR CANADIAN ASBESTOS PRODUCERS, 1971

Name of Company	Output (Mill Capacity)	Principal Shareholder
Canadian Johns-Manville Company Ltd.		Johns-Manville Company Limited
Jeffrey Mine	33,000 tpd	100%
Asbestos Corporation Limited		Canadair (General Dynamics 100%)
British Canadian Mine	12,400 tpd	54.6%
King-Beaver Mine	12,000 tpd	
Normandie Mine	7,500 tpd	
Johns-Manville Mining and Trading Limited		Widely Held
Reeves Mine	5,000 tpd	
Cassiar Asbestos Corporation Limited		Data unavailable
Cassiar Mine	2,400 tpd	
Clinton Creek Mine	4,100 tpd	
Lake Asbestos of Quebec Ltd.	9,000 tpd	Data unavailable
Advocate Mines Ltd.	5,000 tpd	Data unavailable

Source: Financial Post Index of Mines, 1972.

Thus, the mines in Canada serve as sources of raw materials for foreign plants. Probably the managements of these Canadian operations are evaluated on their ability to provide low cost sources of asbestos fibre. In this context, cost reducing process innovations can be seen as important elements of the corporate strategy of these firms.

The first potash mine in Canada came into production in 1962. Since that time a total of ten mines have been developed in Saskatchewan, the location of one of the largest known deposits of potash in the world. Table 2.15 shows the date each mine was brought into production and its operating capacity.

TABLE ~~2.10~~ 2.15

POTASH MINES IN SASKATCHEWAN, CAPACITY AND OWNERSHIP

Mine	Capacity (Tons)	Principal Shareholder
IMC-K1	2,000,000)	International Minerals and Chemicals
IMC-K2	2,500,000)	
P.C.A.	700,000	Potash Company of America
Kalium	750,000	Unknown
Alwinsal	1,000,000	Unknown
Allan	1,500,000	Texasgulf Incorporated
Vade	1,200,000	Cominco Ltd.
Noranda	1,200,000	Noranda Mines Ltd.
Duval	1,000,000	Unknown
Sylvite	1,000,000	Hudson Bay Mining and Smelting Co.

Source: Canadian Minerals Yearbook, Queen's Printer, Ottawa, 1971.

The rapid expansion of capacity in the industry led to a severe price decline, followed by the institution of production controls by the Government of Saskatchewan. These controls reduced the operating rate of the potash mines to approximately 40% of capacity in 1971. Under these conditions, factor productivity became a key element in whether or not the mine could be operated at a profit. The Hudson Bay Mine at Rocanville was able to remain profitable only because the management had introduced a continuous mining method at the operation. Company officials doubt that the mine would have been profitable if conventional mining technology had been utilised. 13

The potash mines in Saskatchewan frequently represent horizontal diversification of a large firm such as International Minerals and Chemical Inc., which is already mining potash elsewhere in the world. These mines also represent horizontal diversification by firms in the non-ferrous mineral industry in Canada, as in the case of both Cominco Ltd. and Noranda Mines Ltd. None of the mining operations in Saskatchewan have themselves diversified or expanded the scope of their operations. However, several of the parent companies have either integrated forward into fertilizer manufacture or have entered into join agreements with fertilizer manufacturers to assure a market for the mineral production of their mine.

In the non-metallic mineral industries considered in this research, there are a total of 22 firms active in Canada. Few published data are available on the mineral revenues of several of these firms as they are subsidiaries of larger companies. The mineral revenues derived for these firms to enable the classification shown in Table 2.16 have been obtained by multiplying published prices 14 for both potash and asbestos and multiplying by the capacity for each operation.

TABLE 2.16

MINERAL REVENUES OF FIRMS IN THE NON-METALLIC MINERAL INDUSTRY IN CANADA

Range of Mineral Revenues	Number of Firms
$ 00 to $ 40,000,000	18
$40,000,000 to $100,000,000	2
Over $100,000,000	2

2.6. SUMMARY

The data presented in this chapter have enabled us to define a population of mineral industry firms for the research whose mineral revenues are classified as shown in Table 2.17.

TABLE 2.17

CLASSIFICATION OF MINERAL REVENUES FOR THE TOTAL POPULATION OF FIRMS RELEVANT TO THE RESEARCH

Range of Mineral Revenues	Number of Firms
$ 00 to $ 40,000,000	124
$40,000,000 to $100,000,000	24
Over $100,000,000	13

In the non-ferrous mineral industry productivity appears to have remained the same, or in the case of gold mining, to have declined during the last decade. Even though trackless mining, which greatly reduces capital investment, has been widely adopted by the industry in this period it appears that the output for each unit of factor employed has not increased. The implication of this stagnation in factor productivity may be that, as factor costs rise in the future, profits will shrink unless firms are able to raise the prices for their products. This shrinkage will mean that less funds become available for re-investment in new mining ventures. As ore bodies are depleted, mining firms may not have the reserves of minerals available to provide continuity of operations.

Productivity growth over the last decade is only observed in the ferrous and non-metallic mineral industries. Neither of these industries contain many firms taking risks in growth through exploration or diversification.

Consequently, managers may seek to improve performance through more efficient production. This may entail some risk in the acquisition of new process technology. However, the rewards for undertaking this risk may be high, particularly as most of these firms are raw material suppliers and performance may be evaluated on cost minimisation.

The current growth strategy of many firms in the non-ferrous mineral industry appears to be based on the discovery and exploitation of mineral deposits which can be extracted using existing process technology. In the short term such a strategy might prove successful. However, as these relatively high grade deposits are depleted, the survival and growth of the individual firm will depend on its ability to make lower grade, more remote mineral deposits economic. Firms in the ferrous and non-metallic mineral industries will face the challenge of remaining as suppliers of raw materials to processors at lower cost than can other firms in foreign lands. Thus, to remain competitive in world markets in the future, Canadian firms in all three mineral industries must acquire new process technology that enables them to remain low cost producers able to compete with foreign firms having other competitive advantages.

The strategic choice for managers under these conditions can be seen as including the selection of an effective means of acquiring new process technology. The adoption of new process technology will bring an increase in uncertainty into the management environment. The dilemma in which managers are placed is that of deciding whether or not the firm should invest financial and human resources to provide a flow of new process technology. This new technology, if successful, may provide the firm with an advantage over its competitors. Initially, however, the success of these innovative activities will be uncertain. The alternative, the purchase of new process technology from specialised suppliers, also have an uncertain outcome. Such a course of action involves uncertainty in the price, specifications and performance of the new process at the time of ordering. In the next chapter we shall consider in detail the advantages and disadvantages of both the 'make' and the 'buy' decision.

FOOTNOTES TO CHAPTER II

1. Watkins, M.H., "A Staple Theory of Economic Growth": The Canadian Journal of Economics and Political Science, Volume XXIX, No. 2, May, 1963, pp 141-158.

2. Hedlin Menzies and Associates Ltd., Thompson, Manitoba: A Historical Impact Analysis of Resource Development, Toronto, 1970.

3. The Canadian Minerals Yearbook, Department of Energy Mines and Resources, Queen's Printer, Ottawa, 1973.

4. "Metals Review," The Northern Miner, Vol. 60, No. 47, February 6, 1975.

5. Mining in Canada: Facts and Figures, The Mining Association of Canada, Ottawa, 1974.

6. Dawson, J., Productivity Change in the Canadian Mining Industries. Study Number 30, Economic Council of Canada, 1971.

7. Ibid., pp. 29-30.

8. Corporations and Labour Unions Returns Act, Ottawa, Statistics Canada, 1973.

9. "Inco, a Giant Learns to Compete," Fortune, Vol. XCI, No. 1, January, 1975.

10. The Story of Hudson Bay Mining and Smelting Co. Ltd., The Hudson Bay Mining and Smelting Co. Limited, Flin Flon, Manitoba, 1972.

11. Fortune, ibid., January, 1975.

12. Corporations and Labour Unions Returns Act, Ottawa, Statistics Canada, 1973.

13. Information obtained during discussions with the Chief Executive of the Hudson Bay Mining and Smelting Company Limited, Toronto, November, 1973.

14. "Metals Review," The Northern Miner, Vol. 60, No. 47, February 6, 1975.

CHAPTER III

LITERATURE, THEORY AND PROPOSITIONS

3.1 ORGANIZATION AND INNOVATION

The process of innovation can be carried out by one functional area inside the firm or can be broken down into several different functional areas. Bright[1] suggests seven stages by which the progress of an innovation can be determined. These are:

Stage 1. "The starting point

> . . . which seems to emerge in one of three ways; by scientific suggestion, meaning the speculations, hypotheses, and inferences of the scientist and engineer arising out of his search for new knowledge; by discovery, meaning the identification of new phenomena in the course of pursuing scientific and engineering activities; and by recognition of need or opportunity . . .

Stage 2. The proposal of theory or design concept

> . . . implying crystalization of theory or design concept that is ultimately successful; usually culmination of much trial and error . . .

Stage 3. Verification of theory or design concept

> This stage is marked by the accomplishment of the experiment that confirms the validity of the proposed theory or design concept. It implies demonstration of an effect or a phenomenon as distinct from its application to a useful purpose . . .

Stage 4. The laboratory demonstration of application

> This is the first primitive model of the technology concept in a useful form. . . . Between this and the next stage there are numerous trials of alternative configurations, materials, and variations of scales . . .

Stage 5. The field or full scale trial

. . . we must recognise that there are very likely to be failures in the field trials or that results are so imperfect as to require a return to the laboratory . . .

Stage 6. The commercial introduction

. . . marks the time when the technological innovation is believed to be ready for application as acceptable practice . . .

Stage 7. Wide Adoption

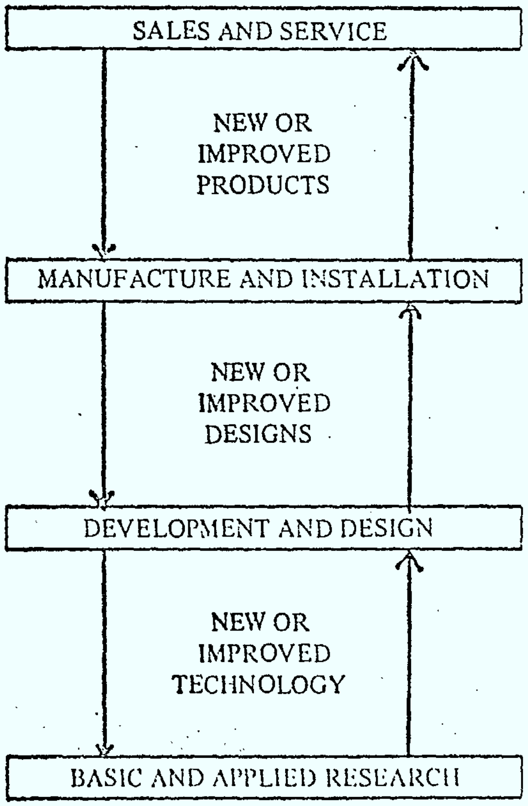
. . . meaning that time when the innovation has achieved usage on a scale great enough to have societal impact as measured by profits to producing firms."[2]

The first six of these seven stages identified by Bright correspond to research, development, and manufacture. Generally, and in this research also, the starting point will be taken to occur at any place inside or outside the innovating organization. Bright's second and third stages will be considered to occur in the applied research laboratory: the proposal and verification of theory or a design concept is the function of applied research. His third and fourth stages will be taken to be the functions of development: turning concepts into working applications. The fifth stage, the field or full scale trial marks the transition of functions between development and manufacturing. At this stage of the innovative process, there is extensive cooperation between the development and manufacturing functions to produce a full scale process from a model application. The commercial introduction and widespread adoption stage are performed by manufacturing and marketing but are not considered in this thesis. This thesis only deals with the activities up to the first innovation and is not concerned with the diffusion of the technology. The latter is a separate issue.

The division of these stages into the functions of applied research, development and manufacturing is supported by Morton.[3] Describing the innovation strategy of the Bell telephone system, he breaks the process of innovation down into these three functions, research, development, and manufacturing. This scheme of organisation is shown below in Figure 3.1.

FIGURE 3.1

FUNCTIONS IN THE INNOVATIVE PROCESS



Numerous studies have shown that industries have different rates of product and process change. Over the last thirty years certain industries have become known for competition on the basis of innovation, whilst others have become noted for their lack of product change. The Organization for Economic Cooperation and Development (OECD) developed the following industrial classification[4]. The purpose of this classification is to group together industries with high, medium, low, and very low rates of innovation. Industries in Group I exhibit high rates, those in Group IV, very low.

Group I	Group II	Group III	Group IV
Science Based	Mixed Industries	Average	Non-Science Based
Aircraft	Machinery	Non-ferrous Metals	Textiles
Electronics	Fabricated Metal Products	Ferrous Metals	Paper
Drugs			Food and Drink
Electric Machinery	Petroleum	Other Transport Equipment	Miscellaneous Manufacturing
Chemicals			
Instruments			

Stinchcombe[5] attempted to relate organizational structure to the age of an industry. For this purpose he developed a classification of industries by age. This classification is shown below accompanied by industries included in each category.

The modern industries correspond to Group I, the Science Based category of the OECD classification. Similarly, pre-factory corresponds to Group IV, the Non-Science Based. Industries in the Railroad Age and Early Nineteenth Century categories correspond to Groups II and III. We can infer that modern

Modern	Railroad	Early Nineteenth Century	Pre-Factory
Aircraft	Transport Industries (except aircraft)	Woodworking	Agriculture
Telecommunication		Leather	Hotels, Lodging
Chemicals and Allied	Metal Extraction and Fabrication	Textiles	Printing
Electrical Machinery and Equipment			Publishing
Petroleum			Forestry

industries have high rates of innovation, but that in mature industries the rate of innovation is much lower.

Amongst these industries, metal extraction (non-ferrous metals and ferrous metals in the OECD classification) can be seen as of the railroad age with an average rate of innovation. This is to be expected, because as was shown earlier, the products of the mineral industries are commodities which change little in specification over time. These commodities are traded in large international markets on the basis of price determined by supply and demand. Producer profit is determined by the ability of the firm to keep its costs below those of other producers.

In many industries the growth of firms depends on their ability to develop new products or new markets for their products. Even in mature industries such as textiles and automobiles competition is based on product differentiation. Processes are uncertain only to the extent that they are affected by changes in product specifications. They are not the main factor in competition between firms.

Research studies in these industries have shown that process manufacture is left to process equipment suppliers. Olsen[6] found that in the United States textile industry the prime sources of process technology are external to the using companies. Equipment suppliers are important sources of process innovations. Abernathy and Townsend[7] suggest that in larger industries such as the automobile industry in the United States, new processes may be obtained from a specialized equipment supplier industry. When process using firms become large they tend to divest themselves of process manufacture. These findings will be discussed at greater length in Chapter VII.

Markham[8] proposes that in mature industries, uncertainty in the business environment is reduced by the development of an oligopolistic industry structure. Under conditions of oligopoly firms are able to control the rate of change of product technology and hence introduce stability into the operations of the firm. One aspect of this stability will be control over process changes. Processes will not be the basis for one firm gaining a competitive advantage over others. Hence their manufacture can be left to specialized suppliers who can obtain economies of scale by selling to all firms in the process using industry. Survival and growth of the process using firm will depend on its ability to exploit new markets and develop new products.

These means of survival and growth are clearly not applicable to firms in the mineral industries. Firms cannot remain in these industries unless they have reserves of ore from which to extract minerals. Minerals cannot be extracted from the ore unless the firm has mastery over the required process technology. Hence, the growth of the mining firm arises from two sources; firstly, the discovery of new mineral deposits, and secondly from possession of the process technology required to extract minerals from the ore at an economic cost.

The basis for competition between firms in the mineral industries can be seen then as not product oriented, but raw material and process oriented. Firms with large ore reserves and dominance in process technology have a competitive advantage over firms with smaller reserves and less knowledge of the process technology. Clearly, the acquisition of new ore reserves and process technology are key elements in the growth strategies of firms in the mineral industries. However, process technology cannot be utilised without mineral deposits being in the possession of the firm. Thus the discovery of new mineral deposits must have higher priority for the firm than the acquistion of new process technology, unless the firm already has high ore reserves for which it requires new processes.

Given that the future uncertainty related to the extraction of minerals from a deposit is unmeasurable, and that the firm has already accepted high risks in exploration for the mineral deposit, then it is natural that the firm will wish to minimize risk in the process technology used to extract minerals from the ore. The utilisation of new process technology would involve unmeasurable uncertainty, because it would not at first be known whether or not the new process would work or how well it might work. Hence there is considerable disincentive for firms in the mineral industries to use new process technology. However, where the firm has considerable resources and can stand the financial and business risk involved it may do so if the potential returns are large enough.

The preceding discussion implies that firms in the mineral industries may act in different ways depending on the level of their ore reserves and the magnitude of their resources. Large firms with considerable resources and substantial ore reserves may devote a portion of those resources to the acquisition of new process technology for the purpose either of gaining a competitive advantage, or for the development of a new ore body that is not susceptible to treatment by existing processes. Small firms with limited ore reserves may devote all their limited resources to the expansion of ore reserves by a programme of exploration. The acquisition of new process technology may be of little consequence to the management of these firms.

Once the need to acquire new process technology is recognised by the management of the firm, then it becomes necessary to develop in the firm the functions required if process innovation is to be brought about. As will be shown in the next section, the functions of research, development and manufacture must be integrated if successful innovation is to take place. This integration can be achieved through the market, by the purchase of innovative activities from specialised suppliers, or it can be achieved administratively, within the firm. Both methods of integration have their advantages and disadvantages. Firms that fail to recognise the most effective form of integration may fail to acquire the needed process technology.

3.2 INTEGRATION

Chandler[9] showed that a change in the business strategy of the firm has to be accompanied by a change in organization structure, in short, "structure follows strategy". Ansoff and Stewart suggested that this was also true for the research and development functions of firms in technology based industries.

Different product innovation strategies require different means of integrating (or 'coupling') the research, manufacturing and marketing functions. Two basic innovation orientations were identified in their paper:

> ". . . Rather than attempt to formulate a generally acceptable definition of the two concepts, we shall simply use the terms "R-intensive" and "D-intensive" to denote a tendency toward the basic and experimental on the one hand, and a tendency toward commercial product design on the other."[10]

They identified three degrees of coupling: high, medium, and low which are shown schematically in Figure 3.2. These degrees of coupling are based on the extent of the information flow between the different functions. Clearly, low coupling exists where little market input is required for manufacturing and little manufacturing input for research and development. Conversely, high coupling takes place where there is a need for research and development to be aware of both manufacturing and marketing constraints.

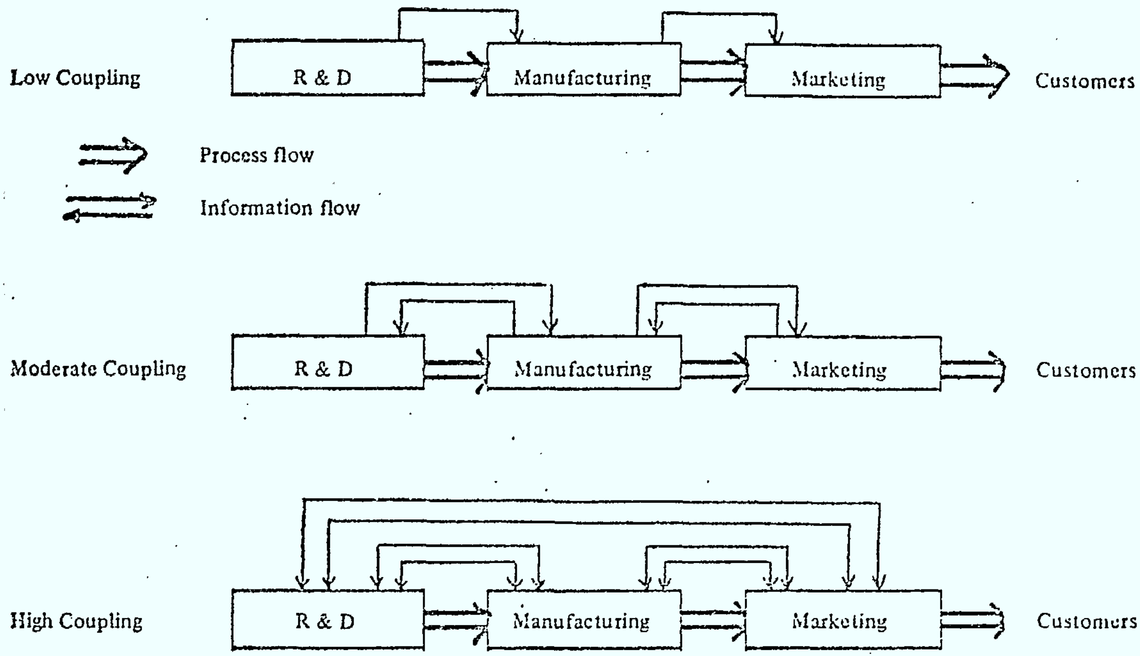
Based on these orientation and coupling characteristics, Ansoff and Stewart identify four marketing strategies. These strategies determine the research and development strategy of the business. They describe these strucutres as follows:

1. "First to Market

   This risky but potentially rewarding strategy has a number of important ramifications throughout the business: (a) a research-intensive effort, supported by major development resources, (b) close downstream coupling in product planning and moderately close coupling thereafter, (c) high proximity to the state of art. . . ."

FIGURE 3.2

COUPLING STRATEGIES



Source: Ansoff, I. and Stewart, J. M., "Strategies for a Technology Based Business": Harvard Business Review, Nov.-Dec., 1967, p. 71.

2. "Follow the Leader

   This marketing strategy implies: (a) D-intensive technical effort, (b) moderate competence across the spectrum of relevant technologies . . . (d) high downstream coupling of R & D with marketing and manufacturing. . . ."

3. "Application Engineering" . . .

4. "Me–too".[11]

The need for coupling is also discussed by Morton in his book referred to earlier. He describes the Bell Telephone organization as follows:

> "Out of Bell Labs come the designs, requirements, and manufacturing specifications for the new and improved hardware and software which Western Electric produces and purchases."[12]

> "As our organism has grown in response to larger possibilities and purpose, our specializations have had to increase and we have become decentralized in space and organization. As a result it is the basic nature of the couplings that has required much of our management innovation as we responded to the need for increased specialization. It is the couplings among and within AT and T, Bell Labs, Western Electric, and the operating companies that have required the hardest thought. . . ."[13]

Morton then discusses the trade off between the separation and integration of the research and development functions, and manufacturing:

> "When R & D is too intimately mixed with manufacture urgent manufacturing problems bring long term research and development to a halt, and it is difficult to depart very much from existing products and technology. . . .
>
> But total autonomy and isolation are not the answer. If you isolate R & D, how can research people know about the Bell System's problems and select areas of relevant science? . . . How can development people determine the economic manufacturability of their designs, make tradeoffs between design and process, or balance performance, cost and reliability?. . ."[14]

From the more general standpoint of business policy, Wrigley has considered the problem of integrating research and development with production. A model to predict relationships in various economic states was developed by him to explain the functions carried on within firms. Four key assumptions are made in the development of the model. These are:

"1. All economic activity consists of three things (1) integration, (2) R & D, and (3) production. These activities are undertaken by persons who specialize in one to the exclusion of the other two.

2. Integration consists of relating R & D to production.

3. Two methods of integration are open. First, the market mechanism, which includes (a) search for the relevant markets, (b) negotiations between buyer and seller and the contract of sale, and (c) settlement terms and procedures for contract performance and contract non-performance (in terms of specification and time). Secondly, the administration within a firm including the (a) structure, (b) contract of employment between employer and employee and (c) motivation system.

4. An uncertain world, i.e. where there are unpredictable changes in demand, technology, and resources, with the unpredictability becoming increasingly greater with the further ahead in time."[15]

Wrigley argues that in conditions of uncertainty the most effective way to link research and development with production is administratively:

"Unless the output for R & D can be specified in exact terms as to technical nature and time periods, there is no basis on which the market can integrate production to R & D. This integration has to be performed by administration. . . .

(1) In a contract of sale across the market, it is necessary for the product to be specified in terms sufficient to enable perception of performance and non-performance, and of the amount of damage in the event of non-performance. This requires that the buyer knows what he will want in exact terms. When the future in regard to materials or processes in products cannot be predicted exactly, the buyer cannot exactly specify what he will want in the future.

(2) In a contract of employment, all that is necessary in the contract is the limits to what the employee is expected to do. The details

> can be decided later or by the employee himself
> – to whom it may be a matter of indifference
> but who will respond to perception or corporate
> or colleague needs or instructions. Thus, the
> greater the uncertainty and the unpredictability
> of the future, the greater the tendency to relate
> R & D to production by administration. . . .
>
> When there is uncertainty as to the demand and supply of R & D, the relation between R & D and production must enable direct and frequent face to face contact between the relevant personnel. Given the pressure on time, this means that the same people must meet frequently. Production people could not afford to meet with all the R & D personnel in the world who might have a solution to their problems. R & D personnel cannot afford the cost of search on the market for all production plants who might need their services. Thus, the greater the advantage of face to face contact between the same people in production and R & D the greater the tendency to relate R & D to production by administration."[16]

The present research will use Wrigley's concepts of integration, but will apply the concept of integration to a wider range of functions than he did. Wrigley considered only the integration of research and development with production. In this study three integrative tasks will be considered:

1. Research with development.
2. Research with production.
3. Development with production.

We have seen that Ansoff and Stewart have suggested that different "coupling" strategies do exist within the firm. Morton has outlined the integrative innovation strategy of AT and T. We have also seen that Wrigley has proposed that in conditions of uncertainty administrative integration will be more effective than market integration in implementing innovation strategies. No field research has been carried out either to define the extent and nature of innovation strategies or to examine the effectiveness of integration. The research will attempt to remedy this deficiency.

It is now necessary to examine theories that will enable us to predict how integration is carried out in practice. For this reason we shall look at the theory of the division of labour and examine its implications for what firms will do.

We shall then contrast this theory and its implications with the integrative concepts discussed earlier, and their implications for what firms will do.

3.3 THE DIVISION OF LABOUR IS LIMITED BY THE EXTENT OF THE MARKET

In the *Wealth of Nations*[17] Adam Smith advanced his theorem of the division of labour and the principle underlying the theorem. Smith stated that the division of labour:

> ". . . is the necessary, though very slow and gradual consequence of a certain propensity in human nature . . .: the propensity to truck, barter, and exchange one thing for another."[18]

Smith considered that the propensity of human beings to exchange one thing for another was the result of specialization. As some human beings are equipped to do certain things better than others, it is natural that they should specialize in what they do well. The surplus of their production can be exchanged for money which can in turn be exchanged for the necessities and luxuries of life.

If, as Adam Smith proposes, the division of labour is brought about by the propensity of human beings to barter and trade, then:

> "As it is the power of exchanging that gives occasion to the division of labour, so the extent of this division must always be limited by the extent of that power, or in other words by the extent of the market."[19]

This condition, attached to the theorem of the division of labour allowed Adam Smith to develop the concepts of supply, demand and price. Clearly, if the market demand for a commodity is very small, then specialization in its manufacture is discouraged. On the other hand if the market for a good or service is very large, then its production may be broken down into a series of operations each performed by a specialist in that operation.

From this background George J. Stigler[20, 21] attempted to explain the functions carried on within the firm:

> ". . . the problem of what the firm does – what governs its range of activities or functions."[22]

In the introduction to his paper, Stigler stated:

> "It is the general thesis of this paper that the theorem of Adam Smith which has been appropriated as a title is the core of a theory of the functions of the firm and industry."[23]

According to Stigler, the functions that a firm would perform were not only governed by economies of scale, but also by the extent of the market for a particular commodity:

> "Now consider Smith's theorem. Certain processes are subject to increasing returns; why does the firm not exploit them further and become a monopoly? Because there are other functions

> subject to diminishing returns, and these are, on balance, at least so costly that average cost of the final product does not diminish with output. Then why does the firm not abandon the functions subject to increasing returns allowing another firm (and industry) to specialize in them to take full advantage of increasing returns? At a given time these functions may be too small to support a specialized firm or firms."[24]

These arguments are used by Stigler as the basis for his discussion of the action of firms related to vertical integration. Prefacing his discussion Stigler comments:

> "Broadly viewed, Smith's theorem suggests that vertical disintegration is the typical development in growing industries, vertical integration in declining industries."[25]

In his discussion of vertical integration, Stigler identifies three stages of industrial growth. In future discussions these will be characterized as young, mature, and declining industries. Young industries are described by Stigler as follows:

> "Young industries are often strangers to the established economic system. They require new kinds or qualities of materials and hence make their own; they must overcome technical problems in the use of their products and cannot wait for potential users to overcome them; they must persuade customers to abandon other commodities and find no specialized equipment and often manufacture it, and they must undertake to recruit . . . skilled labour."[26]

As the young industry grows in size, the size of its functions increases. This results in vertical disintegration in the mature industry.

> "When the industry has attained a certain size and prospects, many of these tasks are sufficiently important to be turned over to specialists. It becomes profitable for other firms to supply equipment and raw materials, to undertake the marketing of the product and the utilization of by-products, and even to train skilled labour."[27]

Finally, as the industry begins to decline, and its demand for raw materials and equipment declines, firms in the industry will be forced into vertical integration:

> "And, finally, when the industry begins to decline these subsidiary, auxiliary, and contemporary industries begin also to decline, and eventually the surviving firms must begin to reappropriate functions which are no longer carried on at a sufficient rate to support independent firms."[28]

3.4 LIMITATION OF THE SMITH-STIGLER POSITION

The economic propositions of both Smith and Stigler are centred around the concept of industrial growth. As an industry grows, so its demand for process equipment will grow, enabling other firms to specialize in the manufacture of this equipment. Both Smith and Stigler considered that this would lead to the formation of another industry. The product of this second industry would become the process of the using industry.

Missing from the model developed by Smith and Stigler are any considerations of change in the operations of the process using industry. Changes in operations necessitate changes in process equipment. These changes may be either radical or incremental. In either case research, development and process manufacture are necessary to bring about these changes. Neither Smith nor Stigler takes a position on the division of labour related to the innovative activities for new process equipment or how specialized activities will be integrated.

However, from the Smith-Stigler argument we can infer the following development of activities in the process using industry:

1) As a young industry, firms in the industry would research, develop, and manufacture their own process equipment. This action would be necessary due to the small size of the market for process equipment.

2) As the industry grows, so firms in the industry will grow in size and new firms will enter the industry. The market for equipment will grow, and firms will specialize in the manufacture of process equipment for the industry, thus creating a new equipment supply industry.

3) The mature industry will do no process equipment manufacture. New firms entering the industry will be able to acquire their process equipment from the specialized supply industry.

4) Even in the mature process using industry, firms would experience requirements for innovation in process technology. As the firms in the process using industry have no capability to manufacture this new technology, and the process equipment supply industry has a market position to protect, we would expect that the manufacture of this new process technology would be done by the equipment suppliers.

5) Given that it is economic for the suppliers to manufacture the process equipment, they should wish to carry out the research and development for their new product which is to be a new process for the using industry. This

preference occurs because they can specialize in the performance of the research and development on a more economic scale than the users of the technology each doing their own, in much the same way as they specialize in the manufacture of the technology. That is to say if it is uneconomic for using firms to manufacture their own process equipment but economic for specialized suppliers, then it follows that it will be economic for suppliers also to specialize in research and development whereas it will not be so for users.

If this were the case then, according to our extension of the Smith-Stigler position we would expect to find little research and development of process technology in the mature process using industry. Rather we would expect to find these functions concentrated in specialized equipment suppliers along with the manufacture of the technology.

3.5 SUPPORT FOR THE EXTENSION OF THE SMITH-STIGLER POSITION

In a study of the new product process in the machine tool industry, Little proposed that the supplier of process equipment was the most effective source of research, development, manufacturing and diffusion of the new process because of his ability to specialize in these functions.[29] Little developed a new model of the new product process for the machine tool industry. He developed the model from previous models describing the new product process. This new model he called the Gatekeeper model. The Gatekeeper model incorporates three prior models: the Job Shop Model, the Leader Model and the Science Model. We shall describe briefly these models, and then discuss the Gatekeeper model and its implications.

The Job Shop Model is illustrated in Figure 3.3. This model applies to the products of machine tool manufacturers that are useful in the processes of only a limited number of users. The model describes the functions of process conceptualization, research, development and specification as integrated in the activities of the process using firm. The function of the machine tool builder is to manufacture the product to the specifications supplied by the user.

The Leader Model describes the development and manufacture of machine tools which are applicable to a wide range of processes.

> "Whereas the Job Shop Model products have their origin in a single manufacturers production process, the Leader Model products begin with the identification of common process problems for a broad cross section of manufacturers. The builder develops a technologically advanced machine tool that can be sold in standard form to a wide market. New research may or may not be part of the product's technological advance."[30]

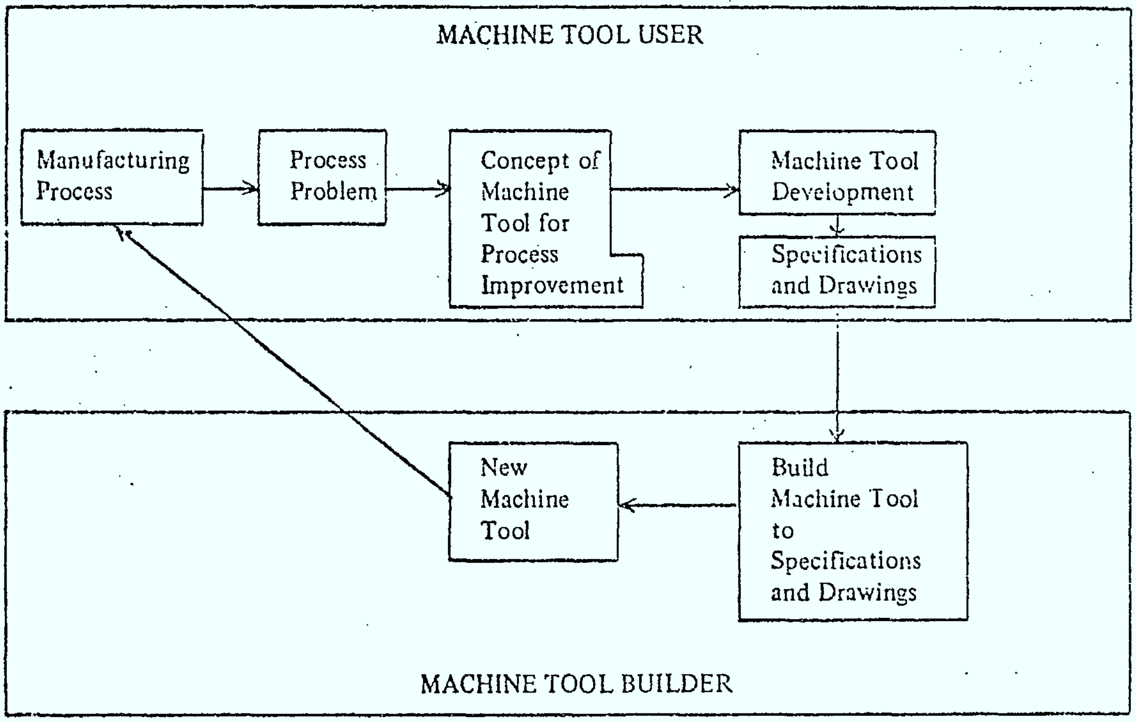
Little notes that this type of innovation may be adopted by process users even though the new process may not completely solve his current process problem. However, the process using firm will generally find it profitable to adopt the new technology. The Leader Model is illustrated in Figure 3.4.

The Science Model represents the development of new products from scientific advances within the supply industry. Little comments:

> "Product innovation based on scientific research is followed in several other industries, including the three principal machine tool industry invaders — electronic, chemical, and aerospace industries. The process of

FIGURE 3.3

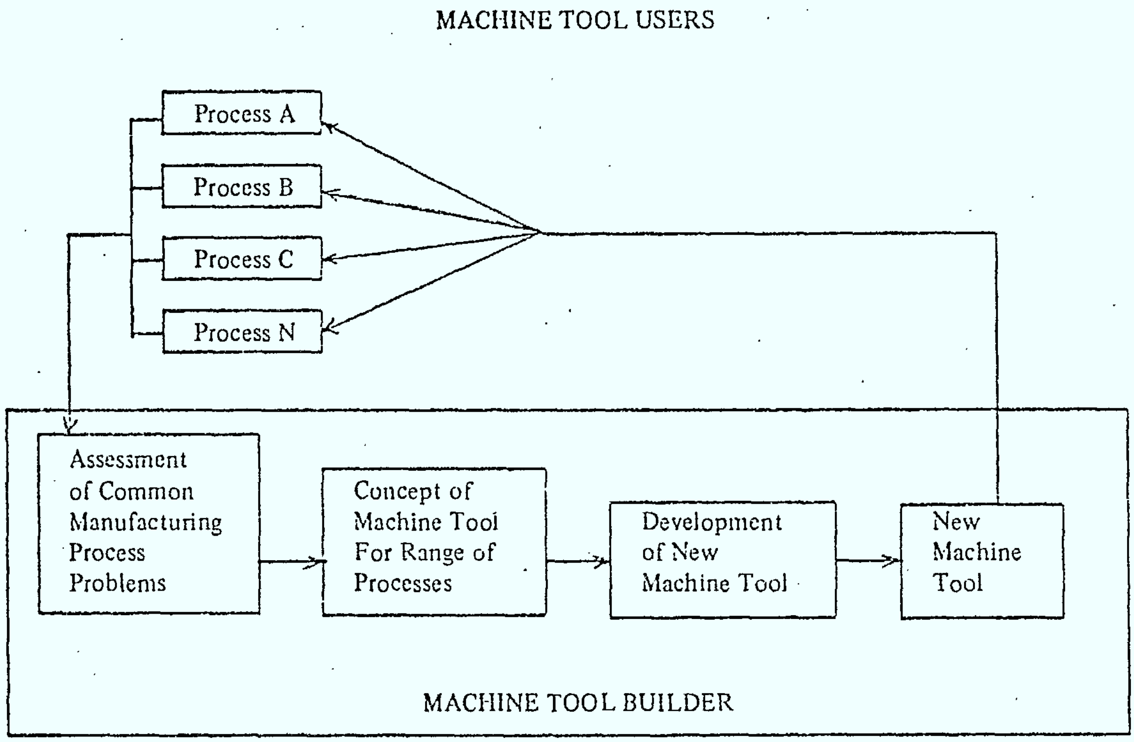
JOB SHOP-MANUFACTURING MODEL OF THE
PRODUCT INNOVATION PROCESS



Source: Little, B., *New Product Information Processing: A Descriptive Study of Product Innovation in the Machine Tool Industry.* Unpublished Doctoral Dissertation: Cambridge, Mass., Graduate School of Business Administration, Harvard University, 1967.

FIGURE 3.4

LEADER MODEL OF THE PRODUCT INNOVATION PROCESS



Source: Little, B., *New Product Information Processing: A Descriptive Study of Product Innovation in the Machine Tool Industry.* Unpublished Doctoral Dissertation: Cambridge, Mass., Graduate School of Business Administration, Harvard University, 1967.

> innovation begins with basic research which spawns new knowledge for applied research and product development."[31]

The process using firm is only involved in the science model as the recipient of the new technology. The functions of basic research, applied research, development and manufacturing are all integrated in the firm supplying the new technology. The Science Model is illustrated in Figure 3.5.

Little describes the Gatekeeper Model as follows:

> "The Gatekeeper Model proposes that individual firms within the industry may develop new products according to one or more of the Job Shop, Leader, or Science processes."[32]

The Gatekeeper Model confers a twofold role on the Machine Tool industry:

1. To bring together the process needs of the process using firm, and the component technology of component suppliers in the most effective manner.

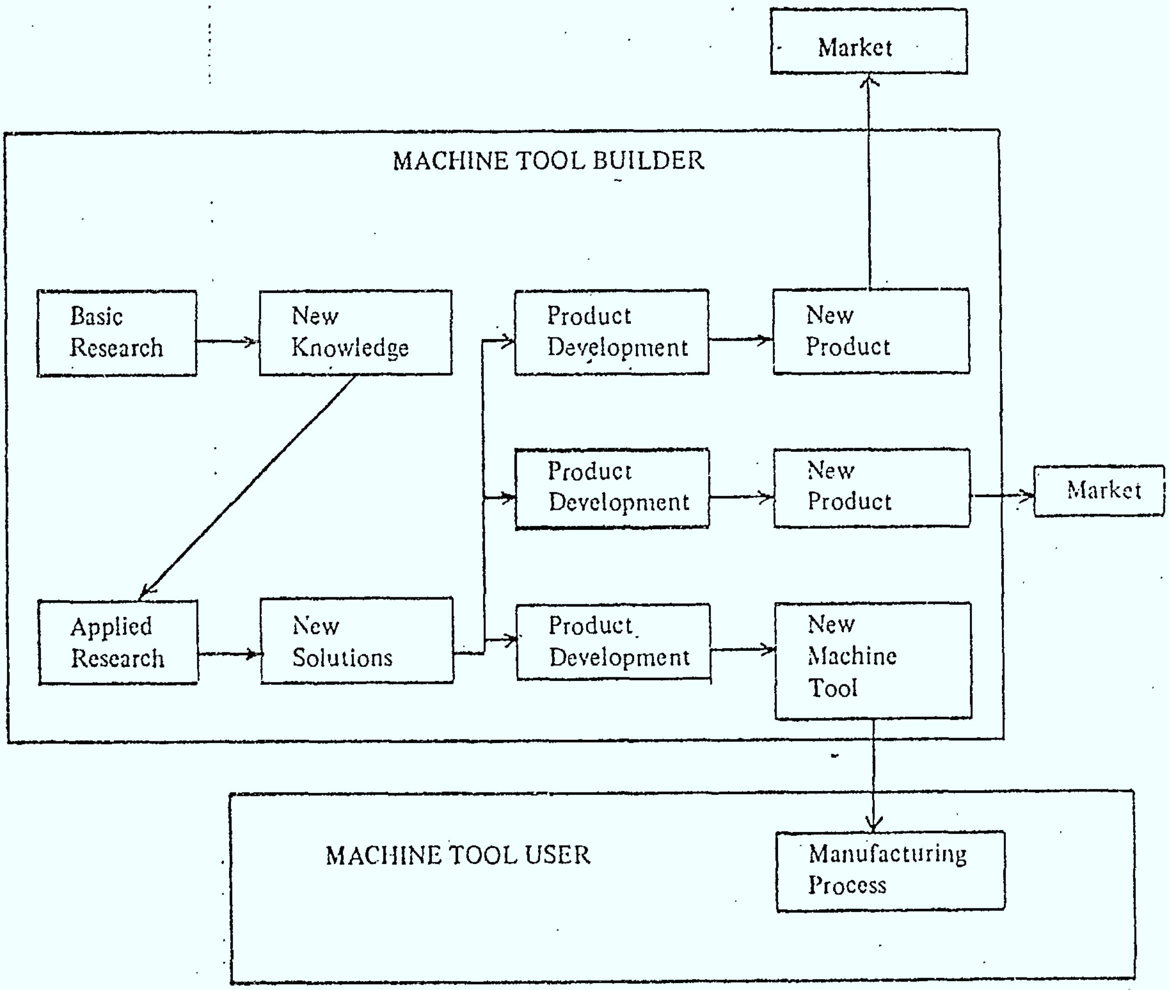
2. To act as the diffuser of new process technology. -

The ability of the machine tool supplier to specialize in the functions of research, development, manufacture, and gathering of new technical information enables it to be more effective than the process user and component manufacturers acting together in developing and diffusing new technology. Little supports the Smith-Stigler position as follows:

> "Where the machine tool industry fails to perceive correctly the process needs of a manufacturer, the manufacturers may develop his own solutions, perhaps going directly to component suppliers for

FIGURE 3.5

SCIENCE MODEL OF THE PRODUCT INNOVATION PROCESS



Source: Little, B., *New Product Information Processing: A Descriptive Study of Product Innovation in the Machine Tool Industry*. Unpublished Doctoral Dissertation: Cambridge, Mass., Graduate School of Business Administration, Harvard University, 1967.

> new profitable component technology. . . . When the [machine tool] industry fails to play the Gatekeeper role, the burden of matching process needs and component technology falls to the manufacturers and the component supplier. This process constitutes a less effective, hence less profitable innovation procedure. Both manufacturer and supplier have interests too broad to permit them to specialize in arranging a match between specific problems and specific solutions. Neither can be as well informed as a "broker" or Gatekeeper whose specialized function is to arrange such matches."[33]

Little's Gatekeeper Model is illustrated in Figure 3.6.

3.6 DISCUSSION OF THE GATEKEEPER MODEL

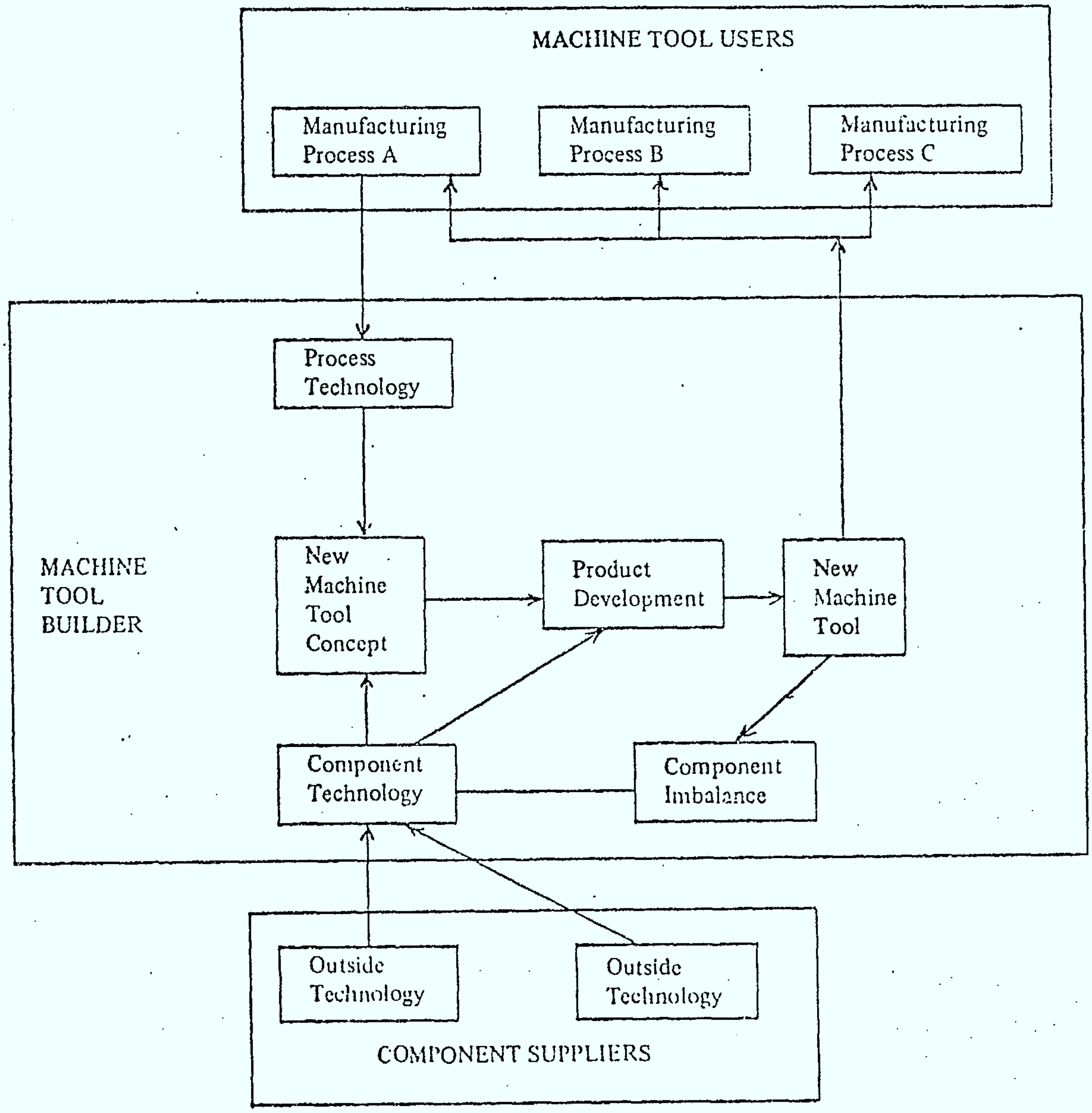
The purpose of the Gatekeeper Model is to describe how a specific innovation would be produced by a supplying industry and diffused to a process using industry. It was not an attempt to describe or predict what long term resource commitments or organization activities related to innovation would be undertaken by either the process user or the product supplier. Little states:

> "The Gatekeeper Model proposes that individual firms within the industry may develop new products according to one or more of the Job Shop, Leader, or Science processes."[34]

However, if the potential user of a new process has no research and development activities, the potential supplier must perform these functions, like it or not, if he ultimately wishes to sell the innovation as a product to the potential user. Conversely, if the user researches, develops and specifies the new process equipment, then the potential supplier can carry out only the manufacture of the process. If the need for the new process technology is initially perceived within the process using industry, then the functions performed by the equipment

FIGURE 3.6

GATEKEEPER MODEL OF THE PRODUCT INNOVATION PROCESS



Source: Little, B., *New Product Information Processing: A Descriptive Study of Product Innovation in the Machine Tool Industry.* Unpublished Doctoral Dissertation: Cambridge, Mass., Graduate School of Business Administration, Harvard University, 1967.

supplier will depend on the functions the process user decides, or is able, to carry out himself.

Let us now consider the on-going commitment of both process user and supplier to innovative activities, rather than the static case of a particular innovation. In this study it is assumed that the commitment of the firm to research, development and manufacturing activities is not made to a particular innovation but rather as a long term organization activity. Firms rarely set up temporary internal organizations for innovation, rather temporary groups to perform specific tasks are formed within a permanent innovative unit. If, firms have research, development and process manufacturing integrated into the organization, then they will tend to use the internal function rather than contract for an external supplier to carry out these innovative activities.

Little proposes that the role of the supply industry as a Gatekeeper or "Broker" of technology and its ability to specialize in innovation will allow it to be more effective than the process using firm in developing new process equipment. If this is so, then we would expect to find an industrial structure similar to that suggested by Stigler with supply firms specializing in research, development and manufacture of products with general application.

3.7 AN ALTERNATIVE THEORY

Wrigley proposed that:

> "Unless the output for R & D can be specified in exact terms as to technical nature and time periods, there is no basis on which the market can integrate production to R & D. This integration is to be performed by administration."[35]

This study assumes that in a mature industry with little product change, but in which there is process innovation, conditions of uncertainty as to future equipment specifications do exist. If Wrigley is correct, then we would expect firms, subject to resource availability to integrate process research, development and manufacture in the same organization. Both Morton and Wrigley suggest that this unit must be the user of process technology as there is need for process research and development to be closely related to the problems and needs of production. Smith, Stigler and Little imply that these activities will be concentrated in the specialized supplier of process technology due to the advantages from economies of specialization.

Innovative activities need not be carried out exclusively by either the specialized supplier or the process user. Process using firms may wish to undertake only limited functions associated with innovation and seek others from specialized suppliers. Specifically, firms may adopt a course of action that utilises internal research but purchases development and manufacturing services from suppliers. Alternatively as Little suggests, firms may use suppliers as 'Job Shops', carrying out research and development of process technology themselves, but seeking suppliers to manufacture.

Each of the above courses of action can be seen as a distinct strategy for acquiring process innovation. They involve the commitment of the resources of the firm to a set of activities designed to achieve purpose. Four possible innovative strategies have been mentioned. These four will be identified below and the activities associated with each specified.

3.7.1 Passive Strategy

The process using firm adopting a passive strategy will have no formal innovative activities in its organization. All research, development, and manufacturing activities associated with process innovation will be purchased outside the firm. Problems and opportunities associated with new process technology may be identified in the firm, but specialized suppliers will be given contracts to conceptualize, specify, and manufacture process equipment to satisfy the needs of the company. Such a strategy takes advantage of the efficiencies of specialization as outlined by Smith, Stigler and Little.

3.7.2 Defensive Strategy

Firms implementing a defensive strategy will integrate research activities into the organization. The purpose of the research organization will be to conceptualize process requirements to meet particular opportunities or solve process problems. The information generated by the research will be used as a basis for specifying the cost and performance of process equipment developed by a specialized supplier.

3.7.3 Active Strategy

Those firms that have integrated research into the organization may find reason (which will be discussed later) to integrate development activities into the firm. The purpose of the development department would be to take the concepts of the research function and produce specifications and working models of a proposed process. This activity would reduce the uncertainty present in a subsequent contract of manufacture with a specialized equipment supplier. At the time of preparing the contract the process using firm will be able to state definite price and performance specifications for the equipment.

3.7.4 Integrative Strategy

As suggested by Wrigley and by Morton, the firm utilising an integrative strategy will not only carry out its own process research and development but it will also control the manufacture of the process equipment. By this action the firm eliminates the need for a contract of manufacture and also the need for a specialized supplier. The firm also assumes all the risks associated with innovation. An integrative strategy may be either simple or compound. Using a simple strategy, the process using firm will utilise suppliers for component manufacture. However, the process using firm will assemble the components to form the commercial process. A compound strategy will involve the process using firm in the manufacture of specialized or proprietary components as well as the assembly of the process. At this stage the firm may enter the equipment market and sell process technology as a physical product to other firms in the process using industry.

Having identified and specified the four strategies that the research propose exist, it is now necessary to establish what criteria will determine the adoption of a particular strategy by a firm and under what conditions the strategy is appropriate.

3.7.5 Selection of Strategy

Smith, Stigler and Little suggested that the nature of the firm's effort to acquire process innovation would be determined by the advantages of specialization. Smith and Stigler implied that specialized suppliers would be induced to manufacture products for the process using industry once the industry has matured. Little suggested that the specialized nature of the particular process required would determine the way in which it was obtained. He proposed that the larger the market for a new supplier product, the more likely it was that the supplier would carry out the innovative effort required. Wrigley and Morton argued that process using firms would tend to organize process innovation activities in their organization because of the advantages from linking research, development and production administratively.

The arguments summarised above centre around the trade off existing between integration and specialization. All firms in a process using industry face the issue of whether it is more effective to allocate resources inside the firm to innovative activities or alternatively to purchase these activities from a specialized supplier. Some firms may possibly perceive advantages from integration, but these may be outweighed by the advantages from obtaining these activities from specialized suppliers.

The thesis of this research is that the critical factor in this decision process is the size of the firm's resources compared to the perceived resources required for effective innovation to take place in the firm. If it is true that firms perceive the adoption of innovative activity into the firm as a long term resource commitment, then allocations of cash and technical staff must be made to these activities for a considerable period into the future. Firms with limited resources may decide that this commitment is not as advantageous as the commitment of funds to a particular innovation through the one time purchase of innovative activities from a specialized supplier. However, as the firm's resources increase, the management of the firm may perceive that the company has the ability to integrate certain innovative functions into the activities of the firm and obtain the benefits of integration, namely the ability to resolve technical problems without being subject to the uncertainties of search and contract in the market.

Using this idea of the limited resources of the firm as the determining factor of the innovative activities of the firm it is now possible to see how firms will expand their activities as they become larger, and why certain activities are undertaken first and others later. In particular we shall concern oursleves with main proposition of this thesis.

3.7.6 Proposition

The range of innovative activities carried out by the process using firm will increase with the size of the firm.

The purpose of management's decision to increase the range of activities will be to reduce the perceived risk in the acquisition of new process technology. This makes the future growth of the firm more certain. A reduction in uncertainty occurs when the integration of activities formerly obtained through the market is replaced by administrative integration. This reduction in uncertainty can only be achieved by integrating these process innovation activities into the firm. The management of the firm must at this point recognise that it is giving up the advantages of specialization for those offered by integration.

Process using firms will not have the resources necessary to integrate all innovative activities in the firm at one time. Indeed it is likely the firm will wish to continue to obtain the cost and skill benefits possessed by specialized suppliers for certain activities. However, as the firm grows we should expect the firm to expand its range of innovative activities through the adoption of a new innovative strategy. The adoption of this new strategy will be marked by an expansion of activities, increasing resource commitments, and additions to the organization structure.

The management of the firm in transition from a passive strategy to active involvement in innovation has to decide which activities to integrate into the firm. We can logically expect that the first will be applied research. There are two principle reasons for this to be so. Firstly, research is the cheapest innovative activity. Research involves relatively low additions to fixed assets, and a department can be initially organized around a small number of staff. Secondly, research is the first step in the innovative process subsequent to problem or opportunity identification. The delineation of required process concepts within the firm will enable it to seek for required process development and manufacturing services from suppliers with lower risk than previously. An estimate of price and performance may now be possible for a contract of sale between supplier and process user, where this could not be done with the process user implementing a passive strategy. This discussion leads to the first two hypotheses of the research.

3.7.7 Hypothesis 1

The group of smallest firms in the process using industry will have no formal innovative activities in the firm. All such activities will be sought from specialized suppliers.

3.7.8 Hypothesis II

The initial commitment to an innovative strategy will be the commitment of funds to applied research in the form of a research budget, and the establishment of a research department. The purpose of this department will be to conceptualise needed process innovations.

The next major expansion of innovative activities will come about with the integration of development activities into the firm. This expansion will occur when the management of the firm perceives a need for greater process development skills in the firm. The integration of development skills will be marked by an increase in the budget allocated to process innovation activities, the formation of groups organized around the development of specific process technology, and the expansion of innovative activities to include the development of process specifications and prototype processes. Specialized suppliers will be utilised to manufacture process equipment with exactly specified performance and price. At this point the firm may begin to trade actively in the transfer of new technical information in the form of specifications and blueprints. Such dealings may be under license or simply an exchange of information. This leads to the third supporting proposition:

3.7.9 Hypothesis III

Firms in transition from a defensive strategy will move to integrate development activities into the firm. The purpose of these activities will be to determine the exact specification of new process technology. The development activities will take the form of determination of specifications and testing of process models by project groups.

The final stage in the expansion of the innovative activities of the firm will come about with the integration of process manufacturing activities into the firm. This will be the last step for two major reasons. Firstly, no manufacturing can be carried out by the firm without process research and development first having taken place. Secondly, the skills required for process manufacture may be very different from those possessed by the firm. Research and development of process technology may be perceived by management as an extension of the skills related to the process technclogy already within the firm. Manufacturing requires a major commitment to new skills and new equipment. For this reason the integration of process manufacture may take place in two phases. The first phase will be the management and control of the assembly of process equipment supplied by specialized component suppliers. The second phase will be the manufacture of special components by the firm itself. At this stage the firm may enter the market as a supplier of process equipment to other firms in the industry by sale or under license. At this point, the firm has reached a stage of total vertical integration into process manufacture. Few firms will reach this stage of development.

3.7.10 Hypothesis IV

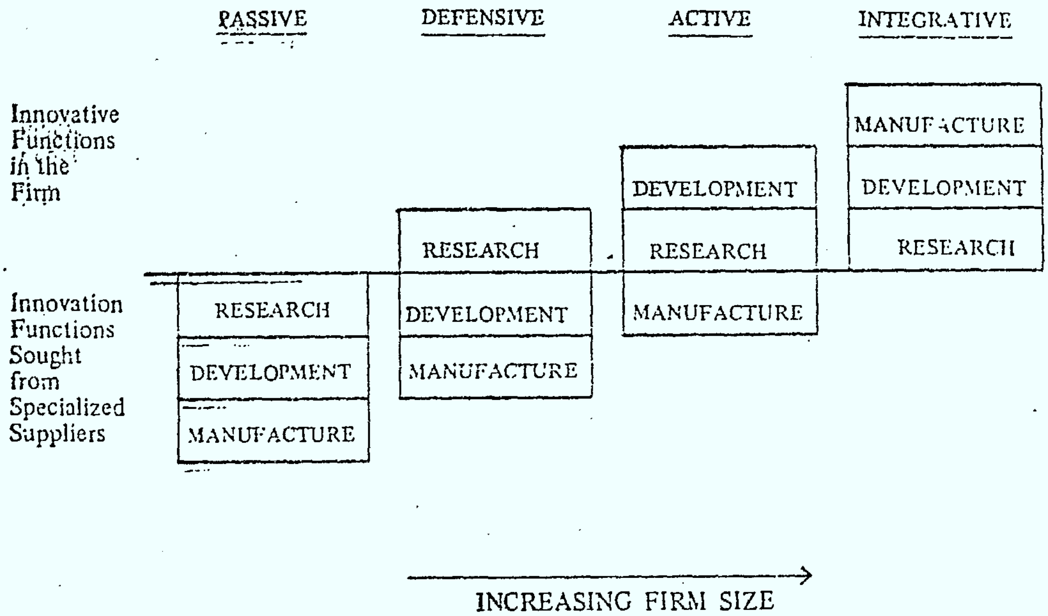
The last stage in the expansion of innovative activities will be the integration of process manufacture into the organization.

These propositions are intended to predict how the innovative activities of a process using firm will grow, and under what conditions these activities will be integrated into the firm. The thesis of the research is that the activities of the firm will increase with its size. The proposition and hypotheses are summarised in Figure 3.7.

It is expected that the thesis research will show the managers in

FIGURE 3.7

FOUR ALTERNATIVE STRATEGIES FOR PROCESS INNOVATION



the Canadian mineral industries are reluctant to implement an integrative strategy. However, it is also expected that the research will show these managers to encounter difficulty in transforming the technical information developed by the innovative activities into commercial processes. They will be reluctant to adopt an integrative strategy because of their limited perception of the business of the firm. They will be unsuccessful in obtaining the manufacture of the process because of the inability to integrate production, research and development across the market. The uncertainty in price and performance will inhibit agreement on a contract for the manufacture of the new process. This reason, it is suggested, is why those firms in industries with low rates of product change are unable to acquire needed process innovation. Specifically the argument is:

> Having little knowledge of the imperatives of product innovation, management of firms with little product change will fail to integrate research and development with the manufacture of new process equipment. The management of the process using firm will attempt to obtain innovative manufacturing services from a specialized equipment supplier. The uncertainty in price and performance specifications will inhibit agreement on a contract. This will prevent the manufacture of the required process innovation.

FOOTNOTES TO CHAPTER III

1. Bright, J. R., *A Guide to Practical Technological Forecasting*: New York, Prentice-Hall Inc., 1973.

2. *Ibid.*, pages 6-9.

3. Morton, J. A., *Organizing for Innovation*: New York, McGraw-Hill Book Company, 1971.

4. OECD, Gaps in Technology, Paris, 1969.

5. Stinchcombe, A., "Social Structure and Organizations," in J. G. March: *Handbook of Organizations*, Rand McNally and Co., Chicago, 1965.

6. Olsen, R. P., *Sources of Process Innovation in the Textile Industry*. Unpublished Doctoral Dissertation: Cambridge, Mass., Graduate School of Business Administration, Harvard University, 1967.

7. Abernathy, W. J., and Townsend, P. L., *Technology, Productivity and Process Change*. Unpublished Working Papers; Cambridge, Mass., Graduate School of Business Administration, Harvard University, 1973.

8. Markham, J., "Market Structure, Business Conduct and Innovation." *The American Economic Review*, Vol. 55, No. 2 (May, 1965).

9. Chandler, A. D., *Strategy and Structure*: Cambridge, Mass., M.I.T. Press, 1962.

10. Ansoff, I. and Stewart, J. M., "Strategies for Technology Based Business": *Harvard Business Review*, Nov.-Dec., 1967, page 71.

11. *Ibid.*

12. Morton, J. A., *Organizing for Innovation*: New York, McGraw-Hill Book Co., 1971, page 39.

13. Morton, J. A., *ibid.*, page 63.

14. *Ibid.*, page 63.

15. Wrigley, L., *R/D and Production: Model Predicting Relationships in Various Economic States*. Unpublished Working Paper, the School of Business Administration, The University of Western Ontario, 1973.

16. *Ibid.*, pages 4-5.

17. Mazlish, B., *An Enquiry into the Causes of the Wealth of Nations, Representative Selections*, Indianapolis: The Bobbs-Merrill Company Inc., 1961.

18. *Ibid.*, page 13.

19. *Ibid.*, page 18.

20. Stigler, G. J., "The Division of Labour is Limited by the Extent of the Market," *Journal of Political Economy*, Vol. LIX, No. 3 (June, 1951).

21. Stigler, G. J., "The Organization of Industry," Homewood, Illinois, Richard D. Irwin, Inc., 1968.

22. *Ibid.*, page 129.

23. *Ibid*

24. *Ibid.*, page 133.

25. *Ibid.*, page 135.

26. *Ibid.*, page 136.

27. *Ibid*

28. *Ibid*

29. Little, B., *New Product Information Processing: A Descriptive Study of Product Innovation in the Machine Tool Industry.* Unpublished Doctoral Dissertation; Cambridge, Mass., Graduate School of Business Administration, Harvard University, 1967.

30. *Ibid.*, page 106.

31. *Ibid.*, page 109.

32. *Ibid.*, page 113.

33. *Ibid.*, page 118.

34. *Ibid.*, page 113.

35. Wrigley, L., *ibid.*, page 4.

CHAPTER IV

PRESENTATION AND DISCUSSION OF THE RESEARCH FINDINGS: HYPOTHESES

4.1 INTRODUCTION

This study proposes that the range of innovative activities in the mining firm will increase with its size. The purpose of this chapter is to use the data collected by means of the mineral industries questionnaire to test the validity of this proposition and the four subordinate hypotheses presented at the conclusion to Chapter III. The analysis of the data presented in this chapter will show that the proposition and hypotheses are supported by the research.

There are three sections in this chapter. The first section briefly describes the relationship of the firms in the sample to the total population of firms in the Canadian mineral industries. The total research and development activities of all the firms in the sample will also be discussed. The second section presents and analyses the questionnaire data with specific attention to the proposition and each of the hypotheses. The final section of the chapter will discuss the research findings in relation to the validity of the proposition, the hypotheses and the model.

4.2 THE MINERAL INDUSTRIES QUESTIONNAIRE

The questionnaire was distributed to the 98 firms listed in the 1973 Financial Post Survey of Mines as active mining firms. Forty completed replies were received by the final acceptance date. The distribution of questionnaires and subsequent replies is shown in Table 4.1. Firms with mining operations in more than one industry are classified in the industry from which their major revenues accrue.

TABLE 4.1

DISTRIBUTION AND RESPONSE TO THE MINERAL INDUSTRY QUESTIONNAIRE

Industry	Number Distributed	Number Operational*	Number of Replies	Percent Response
Ferrous	12	12	5	41
Non-ferrous	70	65	31	47
Non-metallic	16	16	4	25
Total, all Industries	98	93	40	43

*Questionnaires were sent to firms that were subsidiaries of other firms in the sample. In some cases the parent returned consolidated questionnaires for itself and the subsidiary. These subsidiaries are not included in this analysis.

The responses to the questionnaire provide the study with a biased sample that is not truly a proportional representation of the population of firms in each mineral industry. Table 4.2 shows the number of replies by mineral industry and compares them to the population of firms in each industry as presented at the conclusion to Chapter II. It is apparent that only a small proportion of firms in the non-ferrous mining industry replied to the questionnaire. However, Table 4.3 shows the mineral revenues reported by the sample

TABLE 4.2

REPRESENTATIVENESS OF SAMPLE TO THE POPULATION

Industry	Number of Firms in the sample	Total Population	Sample Firms as a Percent of Total Population
Ferrous	5	15	33
Non-ferrous	31	124	25
Non-metallic	4	22	18
Total all Industries	40	161	25

TABLE 4.3

SALES, MINERAL REVENUES AND TOTAL EMPLOYMENT OF REPORTING COMPANIES BY MINERAL INDUSTRY

Industry	Total Sales ($'000's)	Mineral Revenues ($'000's)	Total Employment
Ferrous	146,800	145,300	4,730
Non-ferrous	4,214,935	3,657,600	80,285
Non-metallic	300,000	299,300	8,110
Total all Industries	4,661,735	4,102,200	93,125

firms to be a high proportion of mineral industry revenues.

The apparent contradiction for the non-ferrous mineral industry between the high mineral revenues reported in Table 4.3 and the proportion of all firms reporting is explained by the stratified nature of the replies. Chapter II showed that there are nine major integrated producers which are much larger than the non-integrated firms in the non-ferrous mineral industry. In this sample are eight of these largest firms. The remaining 23 firms in the non-ferrous industry sample are distributed amongst the medium and small sized firms, of which the total population contains 115. The results for the non-ferrous industry will be biased toward the large firms.

Table 4.3 shows the total sales, mineral revenues and total employment for the 35 firms in the sample reporting such data. These data show that, in general, firms in the mineral industries are not diversified. Only large firms in the non-ferrous mineral industries report significant revenues from non-mineral activities.

4.2.1 Research and Development Activities

Nineteen of the forty firms in the sample budgeted for process innovation activities in 1974. All these firms report the existence of formal innovation programmes. Eight of the firms possess research activities, one firm possesses development activities, and ten firms both research and development. Five other firms reported some informal innovative activities. These five firms with informal activities had neither research and development budgets nor formed department specifically for process innovation. Seventeen firms reported that they had no innovative activities of any kind.

Seventeen firms with research budgets reported their budget allocations to different activities. Table 4.4 shows the allocations to metallurgical

TABLE 4.4

RESEARCH BUDGET: ALLOCATION TO AREA OF CONCERN

Area of Concern	Number of Firms	Dollar Allocation	Percent of Total Research Budget
Product Research	8*	4,329,000	22
Mining Research	9	2,034,000	10
Milling Research	16	3,517,000	18
Metallurgical Process Research	16	9,590,000	50

*Six of these firms have research and development budgets in excess of $500,000.

process research, milling research, mining research, and product research. Metallurgical process research receives 50% of all budget allocations by firms in the sample.

The research and development budgets were also allocated to different kinds of research, as shown in Table 4.5. The three categories used were basic research, applied research and development (as defined in Chapter I). The largest financial budget allocation is to development activities which are normally the most expensive.

The total amount budgeted for research and development by the seventeen firms reporting was $29,070,000 in 1974. To carry out this research effort these firms employed a total of 502 qualified scientists and engineers specifically in research and development activities. Seven firms in the sample, each of which budgeted in excess of $1,000,000 in 1974 for research and development, employed 460 (90%) of these personnel.

TABLE 4.5

RESEARCH BUDGET: ORIENTATION TO RESEARCH AND DEVELOPMENT

Type of Activity	Number of Firms	Dollar Amount Budgeted	Percent of Total Research and Development Budget
Basic Research	8	2,250,000	7.7
Applied Research	16	9,760,000	33.5
Development	11	17,060,000	58.8
Total, all firms	17	29,070,000	100.0

4.3 DISCUSSION OF PROPOSITION AND HYPOTHESES

4.3.1 Proposition: The Range of Innovative Activities Carried Out by Process Using Firms will Increase with the Size of the Firm.

In Chapter III we argued that the range of innovative activities will increase with the size of the firm because the management of the firm wish to reduce the perceived risk in the acquisition of new process technology. A reduction in uncertainty can be obtained when the integration of activities formerly obtained through the market is replaced by administrative integration. This reduction can only be obtained through the organization of activities inside the firm to enable these innovative activities to be carried on internally. The two principal activities to be integrated into the firm are research and development.

Research and development performance is found by this research to increase with the size of the mining company. Two series, each of two regressions, were carried on the data supplied by firms in the mineral industries to determine the relationship between:

1. Absolute firm size and absolute research and development effort.

2. Firm size and research intensity.

In both sets of regressions two measures of firm size were used; mineral revenues and total employment.

The first series of regressions were designed to examine the relationship between firm size and the absolute resources devoted to research and development by the firm. In the first regression the dependent variable was the dollar research and development budget for the firm, and the independent variable was mineral revenues for the firm in 1973. In the second regression the dependent variable was the number of qualified scientists and engineers employed specifically for research and development by the firm, and the independent variable was the total employment of the mining firm. The results are shown in Table 4.6.

The research and development effort of firms in the Canadian mineral industries increases with the size of the firm. The high coefficients of determination indicate a very strong relationship between firm size and the performance of research and development. However, the proportion of the resources of the firm devoted to research and development is small. The slope of both regressions is less than 0.01, indicating that, in general, firms in the mineral industries allocate less than 1 per cent of their resources to research and development.

TABLE 4.6

RELATIONSHIPS BETWEEN SIZE AND RESEARCH AND DEVELOPMENT

Regression	Research Measure	Size Measure	r^{2*}	t ratio	b**	s.d.*** of b	Number of Firms
1.	Research and development budget	Mining Revenue	0.942	22.80	.009	.0004	34
			Slope : b significant at 0.01				
2.	No. of Q.S.E.'s	Total Employment	0.895	17.41	.006	.0003	38
			Slope : b significant at 0.01				
3.	Q.S.E.'s Total Employment	Mining Revenue	0.01	-	-	-	16
			No significance				
4.	S R & D Mining Revenue	Total Employment	0.0002	-	-	-	16
			No significance				

*r^2 is the coefficient of determination
**b is the slope of the regression
***s.d. is the standard deviation.

The second series of regressions investigated the relationship between research intensity and the size of the firm. These regressions were intended to show whether, amongst firms performing process research and development, the proportion of resources devoted to these activities changes with the size of the firm. For the first regression, the dependent variable used was the ratio of qualified scientists and engineers to total employment in the firm, and the independent variable was mining revenues. The second regression used the ratio of the research and development budget to mineral revenues as the dependent variable and total employment as the independent variable. No significance was found in either of these two regressions. We can infer that there exists a significant relationship between research intensity and firm size.

Research and development activities, measured by budgets and the employment of qualified scientists and engineers, have been shown to increase in magnitude with the size of the firm. However, the regressions illustrated in Table 4.6 did not provide information on the range of innovative activities carried on in the mining firm. Data will now be presented which show that not only do the resources allocated to research and development increase with the size of the firm, but so also do the range of these activities.

The firms in the sample were grouped according to their innovative functions in Table 4.7. Three major groups exist, and the firms in each group can be distinguished from those in other groups on the basis of their research and development activities. One firm implements an innovative strategy which is unique in the sample. This firm possesses development activities, but no research. These research activities are purchased from its parent company in the United States.

TABLE 4.7

RESEARCH AND DEVELOPMENT AND MINERAL INDUSTRY REVENUES

Innovative Activities in the Firm	Number Reporting	Mean Mineral Revenues	Range of Mineral Revenues	
			Highest	Lowest
None reported	18	32,400	96,900	2,900
Research only	6	52,800	106,500	14,700
Development only	1	140,000	-	-
Research and development	10	303,800	1,172,800	9,700

"Student's" t test for the difference between means of samples with unknown variance was carried out on the data presented in Table 4.7 to determine if the differences in the mean mineral revenues between the groups were significant. Details of the test are given in Appendix A. The results of the test showed the means to be different at the significance level of 0.05; the level of significance selected for this thesis.

To check the results obtained from Table 4.7, "Students" t test can be used to test for difference in the mean size of firms in the different groups as measured by total employment. The data for such a test are shown in Table 4.8.

"Student's" t test for the difference between the means of the groups indicated that these differences were significant at 0.05.

The results indicate that three distinct groups of firms can be

TABLE 4.8

RESEARCH AND DEVELOPMENT AND TOTAL EMPLOYMENT IN THE FIRM

Innovative Activities in the Firm	Number Reporting	Mean Total Employment	Range of Total Employment Highest	Lowest
None reported	21	504	1,500	45
Research only	8	1,190	2,320	700
Development only	1	-	-	-
Research and development	10	7,021	22,600	750

differentiated on the basis of research and development activities in the firm:

1. A group of firms with no research and development activities, having mean mineral revenues in 1973 of less than $40,000,000.

2. A group of firms with only process research activities, having mean mineral revenues between $40,000,000 and $100,000,000 in 1973.

3. A group of firms with mineral revenues in excess of $100,000,000 in 1973 which have both research and development.

The firms in the sample were classified into three groups on the basis of 1973 mineral revenues to test the size groupings outlined previously. A chi square contingency test was used on the data shown in Table 4.9 to test for differences in the range of innovative activities of the firms in each size group. Details of

TABLE 4.9

1973 MINERAL REVENUES AND INNOVATIVE ACTIVITIES

Mineral Revenues	Number of Firms with no Innovative Activities	Number of Firms with Research Only	Number of Firms with Research and Development
$ 0 to $ 40,000,000	12	2	1
$40,000,000 to $100,000,000	6	4	2
Over $100,000,000	0	1	7

*The chi square test shows that the difference in the innovative activities of firms in each size group are significant at 0.05.

the chi square test are given in Appendix A. The results of all future tests used in this study, if significant, will be shown at the foot of the relevant table.

The chi square test demonstrates that the range of innovative activities of the firm increase with the size of the firm. Together with previous analysis presented in this section these findings support the general proposition of this thesis and show that the magnitude and range of innovative activities carried out by firms in the Canadian mineral industries increase with the size of the firm. The managements of these firms appear to desire an increase in the span of innovative activities as their size increases. However, these activities grow in proportion to the size of the firm; they do not expand by increases in the proportion of resources devoted to research and development.

4.3.2 Hypothesis I: The group of smallest firms in the process using industry will have no formal innovative activities in the firm, all such activities will be bought from specialized suppliers.

Twenty one firms in the sample reported that they had no formal research and development budget and no specialized research and development personnel in the firm. The average mineral revenues of these firms were $32,400,000 and the mean employment 504 in 1973. These means were significantly different from those reported for firms in the sample which had research activities. "Student's" t tests carried out on the data in Tables 4.7 and 4.8 showed the differences to be significant at the selected level of 0.05.

The existence of this group of small firms was confirmed by the data shown in Table 4.9 in which the sample firms were allocated to three groups on the basis of mineral revenues. The smallest size group included firms with mineral revenues between $0 and $40,000,000 in 1973. The firms were then classified according to their research and development activities. Of the firms with no innovative activities, numbering eighteen in total (three firms did not report mineral revenues), twelve reported revenues less than $40,000,000. Three firms with mineral revenues less than $40,000,000 in 1973 had innovative activities in the firm. One of these firms is a Federal Government owned company which is non-profit oriented and whose operations are mainly experimental. This firm mines uranium. The second firm is a ferrous mining operation utilized as a raw materials source by an integrated steel company. At this mine ore reserves are limited and the company is making an attempt to find new processes that will enable agglomeration of low grade ore (increasing the concentration of metal in the shipped concentrate). The third company is a non-ferrous mining operation that cannot be differentiated from other firms in the industry on the basis of data collected in this research.

A chi square test on the data in Table 4.9 shows that the innovative activities of firms with mineral revenues under $40,000,000 in 1973 are significantly different from those firms with mineral revenues over $40,000,000.

The analysis has shown that hypothesis I is valid for this research. A group made up of the smallest firms in the Canadian mineral industries does exist. These firms have no research and development.

4.3.3 Hypothesis II: The initial commitment to an innovative strategy will be the allocation of funds to applied research in the form of a research budget, and the establishment of a research department. The purpose of this department will be to conceptualize needed process innovations.

Chapter III proposed that firms initiating research activities would commit resources initially only to research and not to either development or process manufacture. We expect this commitment to be so because research is the cheapest function to perform and it is the next in the problem solving sequence to problem definition. Thus the firm can obtain concepts from this research activity for needed process technology at a relatively low cost. It can then supply these concepts to process equipment manufacturers for transformation into a commercial process.

A group of firms in the Canadian mineral industries which have innovative functions in the firm dedicated solely to research activities was shown to exist by Table 4.9. These firms are larger than those with no research activities and smaller than those with both research and development. Eight firms carried out research only. The mean mineral revenues for this group of firms were $52,800,000 in 1973. The mean employment in 1973 for the group was 1,190. Both these means are significantly different from those of the firms with different ranges of innovative activities. The difference is significant at 0.05.

The range of mineral revenues for the group of firms with research activities is from $14,700,000 to $106,500,000. In general, firms with mineral revenues between $40,000,000 and $100,000,000 tend to perform only research activities. The data in Table 4.9 demonstrated that four of seven firms with only research activities fall into this size category.

The resource commitment in firms performing only research is substantially lower than that made by firms with both research and development. Data presented in Table 4.10 shows that the average budget for firms with only research was $194,000 in 1974, significantly lower than that for firms carrying out both research and development. A similar relationship is established in Table 4.11 which shows the employment of qualified scientists and engineers specifically for research and development. In firms carrying on research the mean employment of these personnel was 3.6 per firm, significantly lower than for firms with research and development.

The data presented above demonstrates the existence of a group of firms that can be differentiated from other firms in the mineral industries on the basis of their size and the innovative activities that they undertake. These firms are intermediate sized firms which in 1973 had mineral revenues between $40,000,000 and $100,000,000 and which have generated a need for in-house

TABLE 4.10

NATURE OF RESEARCH AND DEVELOPMENT ACTIVITY: BUDGETS

Innovative Activities in the Firm	Number of Firms	Total Research and Development Budgets	Average Firm Budget	Range of Budgets Maximum	Range of Budgets Minimum
Research only	8	$ 1,556,000	$ 194,000*	$ 300,000	$ 50,000
Research and Development	10	$ 27,807,000	$ 2,780,000	$ 10,000,000	$ 100,000

*"Student's" t test showed that the mean budget for firms with only research is significantly less than that for firms with both research and development. Level of significance is 0.05.

TABLE 4.11

NATURE OF RESEARCH AND DEVELOPMENT ACTIVITY: EMPLOYMENT

Innovative Functions in the Firm	Number of Firms	Employment of Qualified Scientists and Engineers			
		All Firms	Mean	Maximum	Minimum
Research only	8	29	3.6*	12	1
Research and Development	10	471	47.1	150	5

*"Student's" t test showed that the difference between the mean number of qualified scientists and engineers for firms with only research and that for firms with both research and development is significant at 0.05.

innovation activities. The research has shown that management chooses to initially undertake research, which is the cheapest function to perform. The research budgets of firms in this group have been shown to be significantly smaller than those for firms with research and development, and the size of the research department is also smaller for these firms.

4.3.4 Hypothesis III. Firms in transition from a defensive strategy will move to integrate development activities into the firm. The purpose of these activities will be to determine the exact specification of new process technology. The development activities will take the form of determination of specifications and testing of process models by project groups.

The integration of the development function into the firm commits the management to actions that utilize the product of research inside the firm. These actions are more expensive than research but depend upon its output for their success. However, Chapter III proposed that the integration of development activities enabled the mining firm to reduce the risk in process innovation through a reduction in uncertainty. This reduction is brought about by the elimination of the market purchase of product development and its attendant price and performance uncertainty.

The existence of a distinct group of firms conducting research and development is shown by Tables 4.7 and 4.8. Ten firms in the sample report research and development activities. The average mineral revenues for firms in this group were $357,300,000 in 1973 and the mean employment was 7,021. "Student's" t tests on these means showed that the mean size of firms in this group is significantly larger than that for firms in the groups with different innovative activities. The differences are significant at 0.05.

In 1973 mineral revenues for firms with research and development ranged from $9,700,000 to $1,172,800,000. The firm reporting the lowest mineral revenues is a Government owned mine in the uranium industry. The activities of this firm cannot be considered typical of firms in the Canadian mineral industries as it does not have economic profit as a primary mission. Its primary purpose is to carry out research and development on the process of uranium extraction.

Of the eight firms in the sample reporting mineral revenues for 1973 in excess of $100,000,000 only two did not carry out both process research and development. One of these firms performed research only and the other development. The firm with research only reported mineral revenues of $106,500,000 in 1973 and had no characteristics that could identify it as exceptional in the industry. The firm with only development activities is foreign owned, in the non-metallic mineral industry, and works closely with its parent's basic and applied research laboratory in the United States.

The absolute innovative effort of firms with research and development is much greater than for those with only research activities. The average research and development budget in 1974 for the ten firms reporting was $2,780,000 and the average number of qualified scientists and engineers employed in these activities was 47 as shown in Tables 4.10 and 4.11. The innovative activities carried on by firms with research and development includes a relatively large proportion of product research. Of all funds allocated to research and development by these firms, fifteen percent are allocated to product research. This product research is intended to develop new markets for existing products or to develop new products for small, specialized markets. The major part of the budget allocation by firms in this group is to metallurgical process research and development.

The preceding analysis demonstrates the existence of a group of firms which carry on research and development and which are the largest firms in the mineral industries. The average research and development budget and the size of the research and development department for firms in this group are both significantly larger than those of other firms in the mineral industries.

4.3.5 Hypothesis IV: The last stage in the expansion of innovative activities will be the integration of process manufacture into the organization.

After a new process device has been specified and experimentally tested by research and development, management must decide how to manufacture or obtain the necessary equipment to bring it into commercial use. At this point in time, the technology exists in the form of information such as blueprints. Inherent in the transformation to a full scale process is uncertainty in the future performance and price. The firm can either utilize the services of a specialized equipment manufacturer or it may choose to integrate the manufacture of the process equipment into its own activities. In Chapter III we argued that some large firms would seek to integrate the manufacture of new process technology into the operations of the firm so that the uncertainty in the market may be eliminated and the advantages of administrative integration obtained.

Interviews with executives in firms with research and development activities ascertained that two firms are active in process manufacture. The one firm in the sample with only development in the firm also reported that it carried on process manufacturing activities. No firms with either research only or no innovative activities were active in process manufacture.

No statistical tests are possible on the manufacturing activities reported by firms in the sample because these firms do not comprise a distinct group. They are distributed amongst the larger firms in the industry which, characteristically, carry out research and development. Firms that do not carry out process manufacture but which have research and development were asked why they did not undertake process manufacture. Executives in three of these firms report that their firms are not engaged in the manufacture of process equipment because, as one executive commented:

> "Our business is to mine ore, not to manufacture process equipment. It is the function of equipment supply firms to do that."

Thus, management perception of the business of the firm appears to play some part in whether or not the firm manufactures process equipment.

The apparent purpose of the process manufacturing activities carried on by the three firms is to eliminate uncertainty in the initial manufacture and operation of the process. None of these firms perceive these activities as continuous. Existing facilities are used to manufacture the first commercial installation and any subsequent manufacture is undertaken by equipment suppliers who can take advantages of economies of scale not available to the process user who manufactures the equipment for his own use only. Then the process using firm which developed the process usually licenses its new technology to other mining firms.

The preceding observations indicate that the integration of manufacturing activities into the firm may occur once research and development are present in the firm. However the decision to integrate these activities appears to be more influenced by senior managements' view of the business of the firm than by size. It seems possible that the manufacture of process equipment is perceived by senior executives as a new business, whereas research and development are seen more as extensions of skills already in the firm. Relatively few firms in the Canadian mineral industries extend their innovative activities to the manufacture of the first commercial process. No firm manufactures process equipment for sale to other firms in the mineral industries.

4.4 THE EXISTENCE OF INNOVATIVE STRATEGIES

The analysis presented so far has been concerned with the proposition and hypotheses stated at the conclusion to Chapter III. With the exception of Hypothesis IV, these have been found to hold within the confidence limits defined as acceptance regions for this study. Hypothesis IV was found to hold for individual firms but not for a distinct group.

The existence of four distinct innovative strategies was proposed on the basis of resource commitments and activities in different groups of firms in the Canadian mineral industries. The analysis has shown that these resource commitments and activities do exist, and that three groups of firms can be distinguished from one another. Therefore we can conclude that the four strategies do exist. These four strategies were characterized as passive, defensive, active and integrative earlier in this work. In the next chapter we shall discuss each of these strategies in some detail.

CHAPTER V

INNOVATIVE STRATEGIES OF FIRMS IN THE CANADIAN MINERAL INDUSTRIES

5.1 INTRODUCTION

In the preceding chapter we saw that the research findings support the proposition and hypotheses central to this study, and that firms in the Canadian mineral industries do have distinct innovative strategies. These strategies have been characterized as: passive, defensive, active, and integrative. The purpose of this chapter is to provide more information on the firms undertaking each of these strategies, the activities associated with these strategies in which they engage and the outcome of the strategies in terms of process patents and licenses.

The chapter consists of four sections. Each section is concerned with a particular innovation strategy. For the firms implementing a particular strategy the following data will be presented and discussed:

1. The nature of the business of the firms undertaking the strategy.
2. The innovative activities of the firms.
3. The patent and licensing activities of the firms.
4. The relationship of the mining firms to process equipment suppliers.

5.2 FIRMS IMPLEMENTING A PASSIVE INNOVATION STRATEGY

The adoption of a passive innovation strategy was proposed in Chapter III to be characterized by the absence of both a research and development budget and department in the firm. Twenty one of the forty firms in the sample reported no research budget or department and can be said to be implementing a passive innovation strategy.

Five of these firms reported some informal innovative activities, but were unable to provide any data on the nature of these activities, the personnel involved, the cost, or the means for evaluating these activities. No specific examples of the outcome of these informal activities were provided by them. Certainly, these activities do not appear to be undertaken as a commitment to long term research and development intended to provide a stream of process innovations.

Eighteen firms in the group reported data on total corporate sales and mineral revenues which showed that they are not at all diversified. As shown in Table 5.1 the mean total sales were the same as the mean mineral revenues. All their activities must take place in the minerals industries. Furthermore, none of these firms are integrated forward into smelting or refining. All produce concentrate which is sold to large integrated smelters in Canada or abroad. Production is, in general, from only one operation. As shown in Table 5.1, the mean number of operating locations for firms in this group is 1.27. The median number reported is 1 and the maximum 4.

Even though firms with passive innovation strategies do not have research and development activities, they do have budget allocations to

TABLE 5.1

CHARACTERISTICS OF MINING FIRMS AND INNOVATIVE STRATEGY

Innovative Strategy of the Firm	Mean Number of Mine Locations	Mean Total Sales 1973	Mean Mineral Revenues 1973	Mean Exploration Budget for 1974
		('000's)	('000's)	
Passive	1.4	32,400	32,400	470,000
Defensive	2.0	56,000	52,800	910,000
Active or Integrative	5.0	357,300	303,800	5,800,000

exploration. Of twenty one firms with passive strategies, only four do not have exploration budgets. These four are all operating in either the ferrous or non-metallic mineral industries as suppliers of raw materials to an integrated parent. As was pointed out in Chapter II, the search for new sources of ore is not considered one of their key tasks.

Patents, one of the proprietary products of research and development, are not considered important by firms implementing a passive strategy as can be seen from Table 5.2. The lack of importance of patents to firms with passive strategies is not surprising. They do not have the skills to enable patents to be acquired, and in fact, very little patent activity is reported as can be seen from Tables 5.3 and 5.4. Only one patent is held by one firm which characterized patents as very important.

This lack of activity in patents is reflected in an absence of licensing activity by firms implementing passive strategies. None issued licenses to

TABLE 5.2

PERCEIVED IMPORTANCE OF PATENTS

Importance of Patents	Innovative Strategy of the Firm: Passive	Defensive	Active/Integrative
Very	6%	0%	30%
Moderately	16%	50%	30%
Slightly	6%	25%	40%
Not at all	72%	25%	0%
	100%	100%	100%

TABLE 5.3

FIRMS HOLDING PATENTS

Innovative Strategy of the Firm	Number of Firms Holding Patents		Number of Firms Not Holding Patents		Total Number of Firms	
Passive	1	(5%)	20	(95%)*	21	(100%)
Defensive	3	(40%)	5	(60%)	8	(100%)
Active/Integrative	8	(80%)	2	(20%)	10	(100%)

*A chi square test shows that firms in the three groups differ significantly in the numbers that possess patents. The level of significance is 0.05.

TABLE 5.4

NUMBER OF PATENTS HELD BY MINING FIRMS

Innovative Strategy of the Firm	Type of Patent		
	Product Technology	Process Technology	Mining Technology
Passive	0	1	0
Defensive	2	4	0
Active/Integrative	54	108	7
Total, all firms	56	113	7

other firms and only one held a license from another firm as shown in Table 5.5 Firms with passive strategies appear not only unwilling to undertake research and development, but also they do not engage in the purchase of new technology through license.

TABLE 5.5

LICENSING ACTIVITIES OF MINING FIRMS

Innovative Strategy of the Firm	Number of Licenses			
	From Canadian Firms	From Foreign Firms	To Canadian Firms	To Foreign Firms
Passive	0	1	0	0
Defensive	0	2	3	0
Active/Integrative	5	22	12	26
Total, all firms	5	25	15	26

Data shown in Table 5.6 shows that firms with passive innovation strategies differ from those with innovative activities as to the source of major process innovations and the rate with which they come about. Thirteen firms with passive strategies report no major process innovation during the last ten years, compared to only one firm amongst those with innovative activities. The majority of major process innovations in firms with passive innovation strategies arise from external sources, whereas those companies with research and development report the majority of major innovations arising internally.

TABLE 5.6

SOURCE OF PROCESS INNOVATIONS

Source of Innovation	Number of Firms with Innovative Activities	Number of Firms with Passive Strategy
Internal	8	1
Joint*	3	1
External	4	4
No Innovation Reported	1	13

*Joint implies innovation jointly by mine and equipment supplier.

The cost of these major process innovations was estimated by firms responding to the questionnaire. In general, companies implementing passive innovation strategies placed the cost in excess of $100,000 and less than $5,000,000 as can be seen from Table 5.12. These estimates tended to be lower than those made by firms with research and development, but significantly in excess of the cost estimates of process equipment suppliers from whom it is expected these firms purchase process innovations.

Firms implementing passive strategies do purchase process equipment innovations from suppliers, but in general, only infrequently as shown in Table 5.7. The median frequency of using suppliers is twice per decade. However, it appears that the majority have at some time purchased the innovative services of equipment suppliers on a one time basis to supply skills not in the firm. Sixteen firms reported that they had used equipment suppliers. Of these firms, ten report using them to produce a process from concept form. Only two of them paid the development costs of the suppliers, but fourteen considered that the supplier had been useful in acquiring process innovation. These data are shown in Table 5.8.

TABLE 5.7

FREQUENCY OF PURCHASE OF INNOVATION FROM EQUIPMENT SUPPLIERS BY MINING FIRMS

	Innovative Strategy of the Mining Firm					
Frequency of Purchase	Passive		Defensive		Active/Integrative	
	(Number of Firms)					
Never	4	20%	0	0%	0	0%
Infrequently	9	45%	2	25%	6	60%
Occasionally	6	30%	6	75%	4	40%
Fairly often	1	5%	0	0%	0	0%
Very often	0	0%	0	0%	0	0%
Total	20	100%	8	100%	10	100%

TABLE 5.8

USE OF EQUIPMENT SUPPLIERS FOR PROCESS INNOVATION

Innovative Strategy of Mining Firm	Number of Mining Firms Perceiving Suppliers as: Helpful	Not Helpful
Passive	14	7
Defensive	7	1*
Active/Integrative	4	6

*A chi square test shows that firms with defensive strategies are significantly different from other mining firms in their perception of the helpfulness of process equipment suppliers. The difference is significant at 0.05.

Firms implementing a passive innovation strategy appear to experience a low rate of process innovation compared to others in the mineral industries. Patent and licensing data show that the informal innovation activities undertaken by these firms result in few processes that are of general application and consequent commercial value. Suppliers, when utilized, are expected to perform a complete range of innovative functions for the mining firm. However, the frequency with which they are utilized is low, and the nature of their innovative activities in Canada is limited as will be demonstrated in Chapter VI.

Although this analysis has shown a low rate of process innovation to take place in small mining firms with passive innovation strategies, it is not sufficient to show that this rate is detrimental to their business success. Further research is necessary to establish a position on this matter and such research is not within the scope of this research.

5.3 FIRMS IMPLEMENTING A DEFENSIVE INNOVATION STRATEGY

In Chapter III we proposed that the adoption of a defensive innovation strategy would be characterized by the presence in the firm of a formal research department and a research budget. Eight firms in the sample reported making such resource allocations and may be considered as implementing a defensive innovation strategy.

These firms do not appear to be diversified to any great extent. The mean dollar sales and mineral revenues for 1973 shown in Table 5.1 indicate that 94% of the total sales for this group are in the mineral industries. Three of the firms are integrated forward into smelting whilst the remaining five sell their products in concentrate form. Production for these firms, unlike those with a passive innovation strategy, is usually derived from more than one mining operation. The average number of operating locations is two, the same as the median. The largest number reported was four.

The research budgets reported by these firms were significantly less than the budget allocations made to exploration. Tables 4.10 and 5.1 show that the amount allocated to research was, on the average, one fifth the size of the budget for exploration. Exploration appears to be more important to these firms than process innovation.

The research budgets for firms with defensive innovation strategies are only allocated to process and mining research. No product research is carried out. The majority of the research budget is equally divided between milling research and metallurgical process research as shown in Table 5.9.

TABLE 5.9

RESEARCH BUDGET ALLOCATIONS FOR FIRMS IN THE SAMPLE

	Firms with Defensive Innovation Strategy		Firms with Active/Integrative Innovation Strategy	
Area of Concern	Number of Firms	Mean Percent of Total Budget	Number of Firms	Mean Percent of Total Budget
Mining research	2	10	6	9
Milling research	8	45	7	18
Metallurgical process research	7	45	9	58
Product research	0	0	6	15
Total, all firms	8	100	9	100

Firms with defensive innovation strategies perceive patents as more important than do those with passive strategies, but less important than others with active innovation strategies, as can be seen in Table 5.2. The research activities in these firms result in few patents. Three companies hold between them six patents, two of which are for product technology. The firm holding these two patents does not now carry on product research.

Little licensing activity is carried on by these mining firms. Table 5.10 shows that only one firm has issued two licenses as indicated in Table 5.5. Two others each possess one license from foreign mining firms.

Firms with defensive innovation strategies cooperate with process equipment suppliers more than other firms in the mineral industries. Six out of eight in this group use equipment suppliers for innovative services as often

TABLE 5.10

NUMBER OF MINING FIRMS ENGAGED IN LICENSING

Innovative Strategy of the Firm	Number of Mining Firms Issuing Licenses		Number of Mining Firms Receiving Licenses	
Passive	0	(0%)*	1	(5%)
Defensive	1	(12.5%)	2	(25%)
Active/Integrative	6	(60%)	4	(40%)

*Percentage figures indicate percent of firms with a particular innovative strategy engaged in licensing.

as once a year and perceive these suppliers to be helpful more frequently than do other mining firms. These data are shown in Tables 5.7 and 5.8. Five companies report using suppliers to produce a new process from concepts. However, only two have paid development costs incurred by the suppliers.

In general, the cost of a major process innovation is estimated by firms in this group to be between $100,000 and $500,000 (Table 5.12). Only one firm estimated the costs to be in excess of $1,000,000. None were able to report the cost of a specific innovation made during the last five years.

Firms with defensive innovation strategies appear to utilize the outcomes of research internally and rarely trade in new technology through patents and licenses. The absence of development from the firm may mean that an innovation cannot be specified to the precision required for patents to be obtained. However, if the products of research are to be brought into commercial use by the mining firms development functions must be purchased. Hence, equipment suppliers are important because they can possibly supply the innovative functions which the mining firm misses. These suppliers are expected to develop and manufacture the process from concepts supplied by the mining firm. Possibly the process equipment suppliers subsequently profit from the sale of the new technology to other firms in the mineral industries.

5.4 FIRMS IMPLEMENTING AN ACTIVE INNOVATION STRATEGY

The presence in the firm of both research and development functions and budgets was stated in Chapter III to characterize the adoption of an active strategy. Ten firms in the sample reported these functions and thus can be said to be implementing an active innovation strategy.

Eight firms in this group reported data on both corporate sales and mineral revenues. Although diversification is not a common strategy, several firms reported a significant proportion of their sales in non-mineral industries. Table 5.1 shows that 16% of the total sales for this group are from diversified activities. All eight firms are integrated forward into smelting, and three of them are further integrated into metal forming. All have more than one mining operation. The mean number of mining operations reported was 5, with the median reported being 3 and the maximum 14.

The innovative effort of these firms is oriented toward metallurgical process research. The major portion of the research and development budget is allocated to this area and, as shown in Table 5.11, nine firms have development groups working on metallurgical process problems.

TABLE 5.11

ROLE OF DEVELOPMENT GROUPS IN FIRMS WITH ACTIVE AND INTEGRATIVE INNOVATION STRATEGIES

Role of the Development Group	Number of Firms Reporting	
	Absolute Number	Percentage of Firms in the Group
Metallurgical process development	9	(90%)
Mining process development	4	(40%)
Product development	4	(40%)
Cross functional, linking research, development, and production	2	(20%)

Cost estimates for a major process innovation were provided by seven out of the ten firms. The estimates made were, in general, higher than those made by others in the mineral industries as can be seen from Table 5.12. These estimated costs are of the same order of magnitude as actual costs of major process innovations reported by four firms in this group. These four reported actual costs of a major process innovation in the range $2,000,000 to $23,000,000. These innovations have been made within the last five years. It is possible that these four are the only companies to realise the true cost of process innovation. This may be so because they have engaged in all activities necessary for process innovation to come about.

Process innovation appears to be fairly important to firms with active or integrative strategies. Comparison of the research and development and exploration budgets shown in Tables 4.10 and 5.1 reveals that they devote nearly

TABLE 5.12

PERCEIVED COST OF A MAJOR PROCESS INNOVATION

Perceived Cost of Innovation	Strategies of Firms Reporting: Passive		Defensive		Active/Integrative	
Over $5,000,000	1	(9%)	0	(0%)	3	(42%)
Under $5,000,000, over $1,000,000	4	(36%)	1	(20%)	3	(42%)
Under $1,000,000, over $ 500,000	3	(27%)	0	(0%)	1	(16%)
Under $ 500,000, over $ 100,000	3	(28%)	4	(80%)	0	(0%)
		100%		100%		100%

half as much effort to innovation as to exploration, a higher ratio than for either of the other groups. Patents are perceived as fairly important to these firms as shown in Table 5.2. They hold a total of 169 patents on mineral industry technology, representing 96% of all the patents held by firms in the sample. Over 60% of these patents are for metallurgical processes. The development activities in these firms probably enables the specification of new processes to the stage where patents can be applied for. It is unlikely that firms with passive or defensive strategies have the skill in the firm to produce specifications to this degree of precision.

The patent activity of these firms is reflected in the licensing activity reported in Table 5.5. Ninety one percent of all licenses held and issued by the firms in the sample are related to firms with active or integrative strategies.

More licenses have been issued by these firms than have been purchased by them. A total of 38 licenses have been issued in the last five years and 27 have been purchased.

The range of innovative activities in these companies and the consequent reduction in the purchase of innovative services from specialized equipment suppliers is reflected in the data shown in Tables 5.7 and 5.8. They utilize equipment suppliers less frequently than do firms with defensive strategies and find them less helpful. The presence of development activities in these mining firms may obviate the need to utilize suppliers for innovative activities other than the manufacture of the process equipment. However, when these firms utilize process equipment manufacturers for the development of a specialized piece of equipment, they are more likely to pay the development costs than those with either a defensive or a passive strategy. Six firms with active or integrative strategies report that they pay these costs when they contract with equipment suppliers for development services.

Firms with active or integrative innovation strategies deal commercially in the purchase and sale of process technology far more frequently than those with other strategies. The activities of these firms in patents and licensing are high compared to others in the mineral industries, and their dependence on process equipment suppliers for new process technology appears low. The commercial value of these innovative activities to the individual firm has not been ascertained directly by the research, but firms indicate in their responses that the outcome of their research and development activities are important to their businesses.

5.5 FIRMS IMPLEMENTING AN INTEGRATIVE INNOVATION STRATEGY

In Chapter III an integrative strategy was proposed to be characterised by the presence in the firm of process research, development and manufacture. The nature of the strategy was proposed as either simple, by which the firm manufactures the process for its own use only, or compound, whereby it sells process technology as working processes to others in the mineral industries. Three firms in the sample were identified as implementing a simple process innovation strategy. These firms do not form a distinct group, although two have both research and development and all three report mineral revenues for 1973 in excess of $100,000,000. The third company possesses only development activities in Canada. Basic and applied research are purchased from its parent in the United States.

The firms cannot be distinguished from others implementing an active strategy by any of the measures used in this research. These three firms possess patents and license process technology to and from other firms.

During the course of discussion with managers of research and development in these firms it was established that the process manufacturing activity is only carried out for the first commercial unit. All subsequent units are manufactured by specialized process equipment suppliers if subsequent units are required. These suppliers can take advantages of economies of scale not available to the mining firm manufacturing only for itself. Frequently the process technology is sold by the mining firm to other firms in the mineral industries under license or on a production royalty basis.

Firms with an integrative innovation strategy report no specific investment in equipment for the purpose of manufacturing process equipment. Existing general purpose equipment is utilized for the manufacture of the process, and specialized components are purchased from suppliers on a job shop contract. The purpose of this integrative strategy appears to enable the firm to retain control of the process innovation until it is introduced commercially and there are no uncertainties in the specification and performance of the process. In order to obtain the advantages of integrating the manufacture of the first unit into the firm, they appear to be willing to forego the economies of scale that would be available to specialized process equipment suppliers who might be used to manufacture the equipment.

CHAPTER VI

DATA PRESENTATION AND DISCUSSION: PROCESS EQUIPMENT SUPPLIERS

6.1 INTRODUCTION

We have frequently referred to the division of process innovation activities between mining firms and process equipment suppliers. Chapters IV and V showed that some mining firms do have a range of process innovation activities. However, the range of these activities decreases in smaller firms. The innovative strategies that these firms implement are dependent on their ability to purchase innovative functions from specialized equipment suppliers. Specifically, firms with passive innovation strategies depend on equipment suppliers for process research, development and manufacture. Firms implementing a defensive innovation strategy obtain process development and manufacture from these suppliers. Firms with active innovation strategies utilize equipment suppliers to manufacture processes.

According to the theories of Little, Stigler and Smith we expect to find process suppliers carrying out a wide range of process innovation activities for mining firms. Morton and Wrigley implied that mining firms integrate process innovation functions and we expect to find specialized suppliers carrying out few process innovation functions for mining firms.

In this chapter we will present information which shows the formal innovative activities of process equipment suppliers to be limited compared to those of firms in the Canadian mineral industries. Research and development budgets, and employment of qualified personnel are both low and we will show that individual innovations must be small compared to those made by mining firms. Process equipment suppliers report that they are unwilling to carry on innovative activities because of the general reluctance of mining firms to purchase the resulting innovations. We will see that those mining firms perceived by suppliers as innovative are the large ones which possess sufficient resources to risk the uncertain outcome of these activities.

6.2 PRESENTATION AND DISCUSSION OF DATA FROM PROCESS EQUIPMENT SUPPLIERS

6.2.1 General Information

The questionnaire presented in Appendix B was distributed to 189 companies that advertised as suppliers of process equipment to firms in the Canadian mineral industries. Completed replies were obtained from 38 firms. Twenty two others replied by letter stating that they could not take part in the research. Reasons given varied from confidentiality to an absence of sales in the mineral industries in Canada. The effective response rate was 22.6%. The firms in this sample produce a wide range of process equipment for the mineral industries. The price of this equipment ranges from $100 to $2,000,000 per unit.

Total corporate sales in 1973 amounting to $386,130,000 were reported by 36 firms in the sample. Sales to the mineral industries by these suppliers in 1973 totalled $76,570,000, approximately 20.1% of total sales. Total Canadian employment of 6413 people was reported in the 38 firms on

December 31 1973. Research and development activities for the Canadian mineral industries are undertaken by fourteen out of the 38 firms in the sample.

6.2.2 Research and Development Activities of Sample Firms

Full time personnel in formal research and development departments were employed by the fourteen firms reporting a formal research and development budget in Canada for 1974. In 1973 these firms had total sales of $56,970,000 which amounted to 14.5% of the total sales of the sample. Mineral industries sales by these firms in 1973 totalled $33,780,000 representing 44.5% of all sales to the mineral industries by firms in the sample. Table 6.1 shows that, although firms doing research and development have lower total sales than those not carrying out research and development for the mineral industries, they derive a greater proportion of their revenues from the mineral industries. There appears to be little or no difference between firms that carry out research and development and those that do not in patterns of ownership, nature of product lines and rate of growth.

The range and magnitude of research and development activities performed by equipment supply companies for firms in the mineral industries are shown in Table 6.2. The mean research and development budget reported is $90,000 in 1974. Approximately 3.0% of sales revenues are allocated to research and development by the eleven firms reporting such data. Over half the allocations are made to development.

The magnitude of these research and development budgets is small compared to those of firms in the mineral industries. The mean research and

TABLE 6.1

PERFORMANCE OF RESEARCH AND DEVELOPMENT BY PROCESS EQUIPMENT SUPPLIERS

Nature of Activity	Number of Firms	Mean Total Sales, 1973	Percentage of Total Sales Made to Mineral Industries 0-49%	50-75%	76-100%
No research and development	24*	$ 17,540,000	15	4	2
Research and development	14*	$ 5,180,000	3	3	5**

*Only 32 of 38 firms reported both total sales and sales to the mineral industries.

**A chi-square test indicates that firms doing research for firms in the Canadian mineral industries have a higher proportion of their sales to the mineral industries than firms without research and development. The test was significant at 0.05.

TABLE 6.2

ALLOCATION OF RESEARCH AND DEVELOPMENT BUDGETS

Activity	Number of Firms	Dollar Allocation to Activity	Percentage of Total Allocation
Basic research	5	121,600	12
Applied research	7	326,100	32
Development	9	556,300	56
Total, all firms	11	1,004,000	100

development budget for firms in the mineral industries is $2,780,000 in 1974. Those firms with only research reported a mean budget in 1974 of $194,000. Clearly, the budget for the process equipment suppliers in the sample does not allow for an innovative effort on the same scale as that for firms in the mineral industries. This suggests that process equipment supply firms in Canada do not focus their innovative efforts on a complete process innovation as do mining firms. Rather, they probably research, develop and manufacture equipment which may form an integral part of a larger process. This innovation may then be supplied to firms in the mineral industries as a component part of a new process.

The possibility that firms in the equipment supply industries focus their research and development only on component parts of a larger process is supported by data on the costs of product innovation shown in Table 6.3. The firms in the sample of equipment suppliers were asked to estimate a general order of magnitude for a product innovation intended for use in mineral industry processes. Twenty two out of twenty six firms reporting estimated the total cost to be under $100,000. Only four reported the cost to be in excess of $100,000. In contrast, estimates of the cost of process innovation were made by firms in the mineral industries in Table 5.12. None of them estimated the cost to be under $100,000. The mean of the reported costs is approximately $1,000,000. This estimate is far larger than that reported by equipment supply firms. The difference in these cost estimates provides support for the notion that the equipment supply firms only play the role of component suppliers in process innovation for the Canadian mineral industries.

At this point note must be taken that one firm which was included

TABLE 6.3

COST ESTIMATES OF PRODUCT INNOVATION

Innovative Activities	Number of Firms Reporting Cost as: Under $40,000	$41-$100,000	Over $100,000
Research and development in the firm	3	6	2
No research and development in the firm	9	4	2
Total, all firms	12	10	4

in the research, but not in the statistical sample carries on an extensive programme of research and development in Canada for firms in the mineral industries. The company is owned by a large, American multi-national enterprise. The management of this firm perceives the Canadian mineral industries to be the most technologically advanced in the world. By locating the research and development centre in Canada, they are able to take advantage of spatial proximity to firms in the Canadian mineral industries. The annual budget for the centre is $2,000,000, approximately twice that for all other suppliers in this research, and approximately of the same magnitude as that of the large mining firms. The management of the Canadian subsidiary report that the closeness to Canadian mining companies facilitates the flow of technical information to the company from these firms. With their cooperation, new products are developed, manufactured and sold in Canada, and subsequently exported to mineral industries in foreign lands. This strategy is considered by the management of the firm to provide it with an advantage over its competitors.

6.2.3 New Product Information

The level of process technology in the mineral industries must depend to some extent on the effectiveness and frequency of new product introduction by process equipment suppliers. In this section the new product activities of process equipment suppliers will be presented and discussed.

Process equipment suppliers with research and development have a higher rate of new product introduction than firms that do not have these activities as shown in Table 6.4. The average age of the newest product in the company line marketed to firms in the Canadian mineral industries is 5 years for firms with research and development and 9 years for those without.

Canadian owned firms appear to have a lower rate of product innovation than firms controlled from abroad and either performing their own research and development or importing new products from a foreign parent. Fifteen of twenty one foreign owned firms in the sample imported product innovations from a foreign parent. Six of these firms also have their own research and development in Canada.

The manufacture of new products in Canada is strongly related to the performance of research and development. New products are generally manufactured in Canada by firms with research and development, but are frequently first manufactured abroad by firms without such activities as shown in Table 6.5.

TABLE 6.4

THE RATE OF NEW PRODUCT INTRODUCTION
1969 to 1974

Ownership of the Firm	Firms Carrying Out Research and Development				Firms Not Carrying Out Research and Development			
	Total Number of Firms	Number Reporting New Products	Total Number of New Products	Average per Firm	Total Number of Firms	Number Reporting New Products	Total Number of New Products	Average per Firm
Canadian	5	3	15	5	9	0	0	0
United States					9	9	25	2.77
	6	6	48	8				
Other					6	6	17	2.83

TABLE 6.5

LOCATION OF MANUFACTURE OF NEW PRODUCTS

Activities in Canada	Location of Manufacture In Canada	Abroad
Firms with research and development	11	1
Firms with no research and development in Canada	7	11*

*The difference between the groups in the location of manufacture is significant at 0.05.

6.2.4 Relationship with Mining Companies

The willingness of the mining firm to innovate appears to be a key factor in inducing the process equipment supplier to perform research and development. Process equipment suppliers report that the contribution to profit by a process innovation may be much greater for a mining firm than the profit to the process equipment manufacturer from the sale of the equipment. Hence unwillingness by mining firms in general to assume some of the development risks of process equipment suppliers may discourage the suppliers from making an ongoing commitment to research and development. In fact, process equipment suppliers do see mining companies as being reluctant to adopt process innovations. This is one of the major obstacles to greater cooperation perceived by the managements of these firms. The three most frequently mentioned obstacles are:

1. The reluctance of mining companies to adopt process innovation.
2. The preference for foreign owned equipment

by some foreign owned mining firms.

3. Poor personal contacts between innovators in the equipment supply firm and the mining company.

Although the obstacles mentioned above do exist, suppliers generally see some mining companies as willing to adopt new process technology. Data show that the large mining firms are perceived as more innovative than small mining firms. Suppliers were asked to name those companies in the mineral industries which are the most innovative. The large firms with both research and development dominate the list as shown in Table 6.6. Asked specifically whether large or small mining firms are more innovative, 40% of the replies received selected large firms compared to 2.5% selecting small firms. These data are shown in Table 6.7.

TABLE 6.6

PERCEIVED INNOVATIVENESS OF FIRMS IN THE MINERAL INDUSTRIES: FREQUENCY OF SELECTION

Innovative Activities in the Firm	Absolute Number of Selections	Frequency of Selection
Firms with Research and Development	48	87%
Firms with Research only	3	5%
Firms with no Innovative Activities	4	8%
		100%

TABLE 6:7

PERCEIVED INNOVATIVENESS OF FIRMS IN THE MINERAL INDUSTRIES: MAJOR SIZE GROUPINGS

Perceived as Most Innovative	Number of Selections	Frequency of Selection
Large mining firms	16	42%
Small mining firms	1	2%
Size not a determinant	17	46%
No response	4	10%
		100%

The data presented in this section complement the data obtained from the firms in the mineral industries. The scale and magnitude of the research and development effort made by process equipment suppliers in Canada has been shown to be small and the relationship between these firms and mining firms has been shown to be limited. The unwillingness of mining firms to contribute to the performance of research and development by equipment suppliers has been mentioned as a major reason for this limited market relationship. It may be that mining firms are unwilling to pay for these activities because their outcome is uncertain in terms of performance and price. Under these conditions, the ability of process equipment suppliers to develop major process innovations for the Canadian mineral industries may be very small.

CHAPTER VII

SUMMARY AND CONCLUSIONS

7.1 INTRODUCTION

Process innovation for the Canadian Mineral Industries appears to be inhibited by a variety of circumstances. Major mining innovations are costly and involve a high degree of uncertainty which even the larger Canadian mining firms find hard to bear. Consequently, small firms devote few, if any, resources to research and development. An innovative supply industry to serve domestic needs and exploit export opportunities does not exist in Canada at the present time.

As was predicted by the model, effective research and development is generally only being carried on by large mining companies. Large resource commitments to process innovation are producing results for these firms. However, a technology gap may be developing within the Canadian Mineral Industries, a gap which increasingly favours the large firms. These firms gain access to new process technology not available to smaller firms. Hence cost competition, based largely on the possession of process superiority, increasingly favours the larger firms. In general, smaller mining firms gain access to new process technology only through suppliers, and as we have seen, the research effort of these firms is small compared to that of the large mining firms.

Canadian Manufacturing firms do not compete in international markets with innovative mining equipment to any great extent. There is no Canadian equivalent to Atlas Copco or Ingersoll Rand. Yet mining executives state that Canada leads in many aspects of mining technology and our expertise is developing mines in many foreign lands. However, the historical development of mining equipment supply has lead to the dominance of distributors and branch plant operations in Canada. Canadian mining firms have not integrated backwards, taking the attitude that they are extraction companies and not equipment manufacturers. Yet Canada does have a large domestic market for mining process equipment. Here exists possibly a great opportunity to develop an international Canadian manufacturing operation based on this market. The outcome could be a firm that would be the Massey-Ferguson of mining.

In the following four sections further support and detail will be given to these assertions. However in the first section the discussion will show that firms in the Canadian Mineral Industries act in the manner predicted by the model. General conclusions on the nature of process innovation will be drawn. The second section discusses the practical implications of the research for managers in industry. The third section considers some implications of the study for public policy and the fourth suggests topics for further research.

7.2 RESEARCH SUMMARY AND CONCLUSIONS

7.2.1 SUMMARY

As proposed in Chapter II, the range of innovative activities undertaken by firms in the Canadian mineral industries has been shown to increase with firm size. The research findings presented in Chapters III and IV support this general proposition.

The four hypotheses describing the manner in which it was expected that innovative activities would grow are also supported by the research findings. Chapter III showed that four innovative strategies exist in firms in the Canadian mineral industries. These strategies have been characterised as passive, defensive, active and integrative. The data presented in Chapter III supported the hypotheses with only one major exception of note. The research did not identify a specific group of firms implementing an integrative strategy. However, three firms were identified that are implementing such a strategy. Two of these are similar in activities and size to those implementing an active innovation strategy. The third firm possesses only process development and manufacturing in Canada. Basic and applied research are carried out for this firm by its parent in the United States. In this sense the firm may be considered to be implementing an extended integrative strategy.

The exception noted above does not affect the general findings of the research. Four innovative strategies do exist amongst firms in the Canadian mineral industries. The nature of these strategies and the principal operating characteristics of the firms implementing them are shown in Figure 7.1.

As firms in the Canadian mineral industries increase in size, functions associated with process innovation are integrated into the firm. The corporate strategy which determines these actions may be explicit or implicit; this research was not designed to investigate the decision making process related to the adoption of an innovative strategy. This process might be the subject of further research. However, the logical inference from these actions is that the managements of larger firms perceive the benefits to be obtained from integrating these activities as greater than the costs incurred.

The smallest firms in the mineral industries do not, in

FIGURE 7.1

CHARACTERISTICS OF INNOVATIVE STRATEGIES

	PASSIVE	DEFENSIVE	ACTIVE	INTEGRATIVE
Innovative Functions in the Firm		RESEARCH	DEVELOPMENT RESEARCH	MANUFACTURE DEVELOPMENT RESEARCH
Innovation Functions Sought from Specialized Suppliers	RESEARCH DEVELOPMENT MANUFACTURE	DEVELOPMENT MANUFACTURE	MANUFACTURE	
Mean Firm Mineral Revenues	$0–40,000,000	$40-100,000,000	over $100,000,000	over $100,000,000
Mean Firm Research and Development Budget	$00	$200,000	$2,900,000	$2,900,000
Patent and Licensing Activity	Low	Low	High	High

general, possess innovative activities. These firms implement a passive innovation strategy which means that innovative services must be purchased from specialized suppliers on a one time basis as required. We may infer that the managements of these small mining firms do not perceive benefits from integrating innovative activities into the firm as sufficient to offset the costs in doing so. However, there are undoubtedly benefits available to these firms from process innovation which could improve working conditions and productivity, reduce cost, and increase profits. The task of management is to find a mechanism to do so in a way that minimises the risk to the firm. At present no satisfactory means appears to exist. Data from both mining firms and equipment suppliers indicates that the present market mechanism is unsatisfactory.

The research findings raise doubts about the ability of specialized process equipment suppliers in Canada to provide innovative services for firms in the Canadian mineral industries. The research showed that the formal research and development activities of these companies is limited and that the individual innovations which they make are low cost compared to the cost estimates of process innovation made by firms in the mineral industries. The reluctance of mining firms to adopt process innovations was cited by these suppliers as a major deterrent to the performance of research and development in Canada.

Process innovation has a different significance to firms in the Canadian mineral industries than to firms in other industries. As a key factor in competition it is both desired and feared. The managements of large mining firms can overcome their fears and innovate because failure is unlikely to ruin the firm. However in the small firm, where a process innovation failure may cause ruin, innovation is shunned. The uncertainty in process innovation purchased through the market causes suppliers to perceive many mining firms as being unwilling to innovate. They are unwilling, but only because mining executives are prudent men. Uncertainty is present in their business through the unknown nature of ore deposits. The introduction of new processes would add an extra and unfamiliar source of uncertainty. Given this reality, process innovation throughout the Canadian mineral industries is only likely if new ways are found to bring it about. These must reduce the uncertainty in innovation for the individual mining firm and increase the probability of success. Such conditions are only likely to be achieved to any great extent through the elimination of market-related uncertainty.

7.2.2 Relevance of the Research Findings to the Literature and the Model

The research findings for the large firms support the arguments of Wrigley and Morton that the advantages of integration will outweigh benefits from the economies of scale available to specialized suppliers. However, the findings for small mining firms support the arguments of Little and Stigler that process users will seek innovations from specialized equipment suppliers who are able to obtain economies of scale by spreading the costs of innovation over a large number of installations.

As proposed earlier both the arguments relating to integration and to economies of scale hold under different conditions. Small firms with limited resources attempt to acquire process innovations as they are required from specialized suppliers. The largest firms in the mineral industries integrate research and development functions into the firm to provide an ongoing stream of process innovations. Medium sized firms attempt to obtain some benefits of integration by having a research programme and some of the benefits of economies of scale by purchasing process development and manufacture as required. As the resources of the mining firm grow, so the criteria for an innovative strategy changes from economy to integration. Management is able to reduce uncertainty in its future process technology needs by lessening the firm's dependance on market purchases. Innovative activities integrated into the mining firm can be directed to short or long term problems and opportunities.

These findings support the model proposed in Chapter II. We argued that in the Canadian mineral industries, there exists very low uncertainty in the future specifications of products. These products are staple commodities traded in markets that approximate the perfect markets of economic theory. Competition in the mineral industries is on the basis of price and the control of mineral reserves. Firms that do not control economic reserves of minerals cannot remain active. The primary activity of mining firms is exploration for new ore reserves to ensure the survival and growth of the firm. Consequently, all other activities in the mining company must compete with exploration for the firm's resources.

Where the firm has limited resources and reserves, all surpluses must be allocated to exploration. Long term commitments to other activities cannot be made if the future of the firm is uncertain. Hence, in small firms, resources will be devoted to exploration, and only to other activities when absolutely necessary. Under these conditions process innovation becomes an activity that must be purchased as required. The firm knows little about the nature of processes required in the future, and if new ore reserves are not discovered there will be no future anyway. Innovation in existing operations is limited by the spectre of failure which would interrupt cash flow, and also by the absence in the firm of any long term innovative capability. The research shows that small mining firms do act in a manner consistent with this description.

Once the mining firm has grown to an intermediate size and its future seems assured over a reasonably long time period, then management may perceive that its ability to compete more effectively depends on recovering minerals at a lower cost than other firms. Also, the mining firm may have discovered deposits of minerals not economic with existing processes. Clearly, the development of new processes cannot be left to chance. Management must move to acquire new process technology. The choice available is either to purchase the new technology from specialized suppliers or to carry on innovative activities in the firm.

The research has shown that these intermediate sized firms integrate research and attempt to purchase process development and manufacture. As was suggested earlier, these actions are probably taken because of the unmeasurable uncertainty present in the acquisition of new processes. At the outset of the acquisition process, the mining firm does not know the process required, its specification, performance or price. The first step in reducing this uncertainty is to integrate research into the firm. Research, as shown by the study is relatively cheap and allows the mining firm to create outline specifications for required processes. Process development and manufacture, which are relatively expensive and not required until the research function has proven successful, are still left to be purchased from specialized process equipment suppliers. Management development and manufacturing services can be purchased from suppliers more cheaply than they can be performed in the mining firm.

Large mining firms integrate development activities. By doing so they are able to patent and license new processes. As has been shown, these companies hold 95% of all process patents and licenses in the Canadian mineral industries. These large firms perceive that possession of proprietary rights to a process enabling cheaper mineral recovery allows the firm to make greater profits than its competitors. Possession of advanced processes may enable the firm to recover minerals from deposits formerly uneconomic. Under these conditions the firm does not want others to have access to all process technology. Also the management of the firm does not wish to leave the development of new process technology to a firm over which it has no control. The advantages to be gained from integrating process development may far exceed the one-time benefits from the economies of scale available to suppliers.

The research showed that three large mining firms integrate process manufacture in addition to research and development. As we proposed earlier, they do so because of the uncertainty inherent in the manufacture of the first commercial process. These firms do not attempt to manufacture subsequent units, but allow specialized suppliers to do so. The actions of these firms provides clear support for the argument that as long as process specifications and performance are uncertain, the advantages of integration are greater than the economies of scale available to specialized suppliers.

We have seen that the arguments of Little and Stigler appear to hold for the small firms in the Canadian mineral industries. These firms attempt to acquire process innovations from specialized equipment suppliers who are able to gain economies of scale through the allocation of costs to a large number of installations. The necessary condition for their arguments to hold is the existence of specialized equipment suppliers with research and development programmes intended to provide a stream of new processes to firms in the Canadian mineral industries.

The research showed that little formal research and development is carried on by process equipment suppliers in Canada. These firms reported that mining firms discouraged such programmes because of their reluctance to innovate. Only the large mining firms, all of which have their own research and development programmes were perceived by suppliers to be innovative. As proposed earlier, the barrier to the acquisition of process innovation through purchase across the market appears to be the uncertainty in specification and performance at the time of purchase. Mining firms, especially small ones, cannot risk the financial losses that would result from new processes that did not perform as well as expected. Individually, small mining firms do not need a stream of process innovations. Collectively, they may well. Their actions indicate that they are unwilling to purchase potential, but uncertain, process imporvements through the market. Consequently we can speculate that these firms would like to integrate process innovation activities, but that these are too costly in relation to the resources of the firm. As a result, innovation in small mining firms is too uncertain to be undertaken.

7.2.3 Conclusions

The research has shown that the Canadian mineral industries are unlike many others in the way firms acquire process innovations. In mining the bases for competition are the possession of ore reserves and the processes allowing minerals to be extracted from them. Leaving the development of new processes to other firms introduces uncertainty into their acquisition in terms of price, performance and specification. Allowing a specialized supplier to control the manufacture of process equipment may eliminate the competitive advantage of one mining firm over another. Hence as resources in mining firms can be spared from exploration activities they are allocated to integrating process innovation activities. Distinct competitive advantages can be gained from this strategy.

In other industries uncertainty exists in the product technology and all uncertainty related to future process technology stems from this product specification uncertainty. In these industries competition is on the basis of product differentiation and firms carry out product research and development in anticipation of gaining a competitive advantage. Once a firm has established a dominance in its product technology and can exclude competitors from the market on this basis, then an oligopolist or monopolistic market structure may emerge.

Under conditions of oligopoly, uncertainty in future process technology may become low and firms can allow activities related to this technology to be left to specialized suppliers. These suppliers may be able to take advantage of economies of scale not available to the individual process user. Abernathy and Townsend suggest this may occur when the process technology in an industry has reached an advanced stage where technological development must be considered as systems problems:

> "Eventually, technological advances need to be treated as systems development problems. A specialized equipment supplier industry may form and be sustained in larger industries to conduct the development of process-specific equipment, since development costs are then amortized over more installations."[1]

Where process innovations arise from specialized suppliers, there can be little competition within the process using industry on the basis of new processes as advances are quickly available to all users.

This situation is not the case in the large Canadian mineral industries. Firms have no interest in seeing process innovations rapidly diffused to domestic, and more importantly, foreign competitors. In addition few mining equipment supply firms have the range of experience that allows them to develop process-specific equipment. In Canada research and development carried out by these firms does not take place on the same scale as that performed by large mining firms. Innovations are much less costly and appear to be components of a larger process, which may have been specified by mining company requirements.

In the Canadian mineral industries there is little incentive for firms to leave process innovation to suppliers. In these industries, process innovation plays the role that product innovation does in many others. We have seen that as the size of the mining firm increases, its management acts to eliminate uncertainties inherent in the purchase of process technology by integrating innovative functions. These actions are necessary if the Canadian mineral industries are to remain competitive in international markets.

7.3 MANAGEMENT IMPLICATIONS

7.3.1 General

Firms in industries other than mining require process innovations if they are to survive and grow. In "commodity" industries, such as lumber and energy, competitiveness is in part based on the possession of superior processes. In mature industries, such as steel-making and basic chemicals, firms with best practice processes are more equipped to compete on price than others.

No matter in what industry, process innovation introduces unmeasurable uncertainty into the business of firms. Price, performance and the specifications of new processes are all unknown until using firms have defined what exactly it is they want. What exactly they want is often not certain until research, development, proto-type operation and much trial and error have all taken place. Consequently, the purchase of process innovations through the market is a difficult activity requiring consumnate management ability and some good luck. Business history is filled with cases of failure in such instances. As in mining, such failures can be very costly, and sometimes, disastrous.

The uncertainty in process innovation presents managers with a major strategic decision. They face the dilemma of whether or not to integrate into the firm innovative activities that could possibly be purchased from specialised suppliers as required. Administrative integration involves a long term commitment of financial, technical and managerial resources if success is to be realised. By taking this decision, which may take four, five or more years to show results, potential economies of scale available to specialized suppliers might be lost and time wasted. However, if integration does not take place, then the risk increases that the desired innovations will not materialise.

This research has shown that managers in the Canadian mineral industries apparently make decisions which increase the range and magnitude of innovative activities in the firm as it grows. Functions are integrated which were formerly only available from specialized suppliers. These specific findings support the more general propositions of Wrigley and Morton that in firms requiring a stream of innovations, unmeasurable uncertainties inherent in market integration must be eliminated. The administrative integration of research and development to production is necessary for success.

In an early article on technological strategies, Quinn pointed out that the scientific and technical programmes of a company exist solely to support its overall business strategy. Specifically, the support of certain low return projects may make possible long run, high return ventures based on the outcome of the initial low return activities:

> "...in ranking potential applied research and development programmes, a simple ordering in terms of relative present value, rate of return or expected profit can be highly misleading. Within a given strategy it may be important to invest in a low yield project supporting Division A than a higher yield project for Division B." 2

Support for seemingly low return research and development projects may be necessary in industries such as mining. These projects, if successful, enable the introduction of processes which facilitate new corporate ventures that would be impossible otherwise. In addition they may permit the continuance of existing operations which would become uneconomic without innovation. Although the research and development required for project viability appears to have a low return, the resulting venture may be extremely profitable.

No attempt has been made here to measure the success of process innovations in terms of profits, growth or rate of return. We cannot then predict the returns from investments in different levels of research and development activity. The effectiveness of the different innovative strategies cannot be compared in these terms. However, it is also apparent from the writings of Wrigley, Morton and Quinn that management cannot use short term measures, such as economies of scale, for making decisions on the adoption of innovative activities. Their outcome is not a cost saving due to economies of scale on specific projects, rather it is measured in the growth of corporate revenues and profits arising from operations that have benefiited from a stream of successful process innovations. Frequently, these revenues and profits bear no relation to the initial outlay on research and development.

This argument implies that an innovative strategy adopted on the basis of potential economies of scale from subsequent production may be incorrect. The firm choosing to purchase certain innovative functions from a process equipment supplier and so share in the economies of scale available to the supplier may never obtain these benefits. The uncertainty of specifications, price and performance inherent in the purchase may prevent the signing of a contract. Even when one is signed, the supplier may not develop the desired innovation.

Suppliers can, however, play a key role in process innovation. Data obtained as part of this research indicated that there are instances of cooperation between mining firms and process equipment suppliers. In general, success is achieved where frequent face-to face contact and cooperation develops a form of administrative integration. Financial arrangements must be flexible enough to allow for uncertainty in specification, performance and price. The equipment supplier must be compensated for unforeseen cost increases, whilst the purchaser has to be able to cry "halt..." if the price becomes too high. The mining firm in such arrangements needs to have managers with some process innovation skills who are able to communicate the firm's needs to the supplier and over time integrate the innovative activities of the two firms. This relationship allows the supplier to act as an extension of the firm for the project duration. Such is not the case in a pure market relationship.

That equipment suppliers can be used to provide process innovation is of importance to small firms in "process" industries such as mining. These firms cannot afford the expense of their own research and development facilities and do not need a stream of process innovations. For them, the purchase of innovative services from equipment suppliers can be a major source of innovation, provided a relationship is developed which eliminates market uncertainty. However, the "process" firms must bear all the risks associated with failure. In such a transaction the purchase should be viewed not solely as the process innovation itself. For a limited period, the innovative resources of the supplier, or a part of them as agreed, must be viewed as a temporary administrative extension of the buyer. Management from both firms must integrate and direct joint activities towards successful process innovation.

From the preceding discussion we can see that process innovation could arise in either the user or the process equipment supplier. In the past both categories appear to have contributed. One complicating factor in the study of process innovation is the Nature of the Beast itself. New processes for users are frequently new products for a supplier. In a world where product innovation has been the key to corporate growth and the source of competitive advantage, process innovation often went along with product innovation or was relegated to suppliers. These suppliers acted as "gatekeepers" and diffused new process technology to many firms, gaining economies of scale (and profits) from wide distribution.

However, in many industries, products are now mature. The rate of product innovation has declined, and it is process innovation that becomes the basis for competition, survival and growth. The Pilkington Glass Company of Great Britain still makes glass, as it has done for many years, but it also now makes profits from the licensing of its "float glass process" which it developed. Like Pilkington Glass, more and more firms are realising that process innovation cannot be left to suppliers, but that it is an integral activity of process users.

7.3.2 Mineral Related Industries

Mining is an uncertain business even without process innovation. Unknown ore grades and structures introduce considerable uncertainty for the business. Consequently, for many firms the presence of uncertainty in both process and ore is undesirable and to be avoided if at all possible. However, at the present time there are significant pressures on Canadian mining firms to innovate. Declining ore grades and increasing costs mean that Canadian mines must lower costs, raise productivity and be able to mine ores formerly uneconomic if they are to remain competitive in International markets. Social movements for safer and cleaner working conditions are being introduced by mine-workers. These changes have to be made in an environment made more uncertain by Government policies unfavourable to the industries.

In large mining firms, uncertainty can be spread across sufficient operations that process innovation in one operation would not endanger the firm if it fails. In these firms considerable resources are committed to long term innovation programmes.In smaller firms the uncertainty cannot be spread. Companies with only one mining operation can suffer severely if process innovation proves unsuccessful. Cash flow may be reduced, endangering debt repayments which frequently exist, especially for new mines. In large mining firms the decision on innovation concerns what amount of resources to commit, what activities to integrate. In smaller firms the decision is whether to innovate at all.

In the large mining firm, the decision on how much research and development and which activities is largely a function of top management's perception of the firm and the nature of its business. As was shown in Chapter II, mining firms rarely diversify, choosing to limit their activities to mining and further processing. However, several have the knowledge, technology and capital to exploit mining processes commercially. In at least one of these firms the decision not to do so stems from the view of the President that the firm is a mining company and that equipment design and manufacture is not its business. The decision is correct so long as the firm earns greater returns from mining than it could from diversification. However, for some mining firms, their skills in research and development could be the impetus for a new direction of growth and profitability in a period when the Canadian mining industry is operating in an unfavourable environment.

Medium sized mining firms with some innovative activities in the firm could benefit from close cooperation with process equipment suppliers in Canada who themselves have similar activities. The development of close working relationships could enable the manufacturing firm to capitalise on the process knowledge of the mining firm, whilst the mining firms would be first to acquire any new processes. In this type of relationship the equipment supplier would probably have the proprietary rights to any innovation. Subsequent diffusion of the technology through the "gatekeeper" effect would take place and the Canadian mining industry in general might benefit. Here again success would depend on the integration of the activities of both firms through administrative means and the elimination of market uncertainty. Failure would probably affect the mining firm more than the supplier.

Smaller mining firms with no formal innovative activities are the most vulnerable to a widening technology gap. Many of these firms adopt a "follower" strategy to process changes. They wait until a new process segment has been successfully adopted by many other firms before acquiring it themselves. The problem of its integration into existing operations and startup has still to be faced, however, requiring special skills.

The adoption of a passive innovation strategy, entailing as it does the small mining firm to be a follower, places it at a competitive disadvantage to larger firms. In many industries the cost of innovation is low enough that small firms can compete against large ones through innovation. In the mining industry uncertainty is so pervasive and the cost of innovation so high that it is difficult for small mining firms to do likewise. As noted earlier they compete by devoting all surplus funds to exploration in an attempt to locate new mineral deposits. They do not require a stream of process innovations, and money devoted to a long term research and development programme is unnecessary. However, it is to their benefit, their workers' and ultimately in the national interest if these firms have access to a pool of innovative skills.

A major step forward could be made with the founding of a research, development and project management organization to work on the technical problems of small mining firms. The purpose of this organization would be to provide a stream of process innovations for a group of small mining firms. This organization should be far more than engineering consultants. Skills available should extend from applied research and development through to start-up and running-in expertise. One of its major functions should be to keep small mining firms informed about process developments. Mining firms could pay a subscription fee to cover the overheads of the organization and a further fee for use of their services. As far as possible, market relationships should be eliminated from dealings with this organization. Mining firms would effectively hire human resources from it for limited periods of time during which they would be effectively members of the mine's technical and management team.

The research showed that in general, mining equipment supply companies do little research and development in Canada. Most commonly they either act as distributors for foreign firms or are subsidiaries carrying out some assembly work. There are, of course, exceptions. These firms cannot be characterised by product or by country of ownership. Amongst them, the highest research and development budget was allocated by the Canadian subsidiary of Joy Manufacturing. The purpose of its research and development programme in Canada is to capitalise on Canadian hard rock mining expertise...."the best in the world". Like Joy Manufacturing these firms have higher rates of product innovation and report significantly higher export activity than firms without research and development.

Not a few mining equipment supply companies reported that they found mining firms to be not very innovative. We have discussed possible reasons why in this study. To encourage mining firms to innovate, suppliers must go beyond the market relationship. Close links need to be established with mining firms and trust relationships have also to be established if innovation is to be a possibility. Firms in the research which have been successful innovators with Canadian mining firms report that they have close contacts with them before and after sales are made. Obviously there are many opportunities for cooperation between mining firms and their suppliers. Working relationships provide the mining firm with a flow of ideas for its operations, but equally importantly provide a rich source of new product ideas for suppliers who are willing to innovate in Canada.

7.4 IMPLICATIONS FOR PUBLIC POLICY

Canada's balance of trade was once again positive in 1976. Examination of the supporting statistics show that, as usual, the resource industries provided a massive export surplus that permitted the importation of a wide range of manufactured goods. This performance was achieved despite recent Government policies that have added a new dimension of uncertainty to the business of mining. The surplus would have been even greater if some of the mining machinery imported had been produced in Canada.

The viability of Canada's resource industries in international markets continues to be significant to the country's continued economic health. However, in the Canadian mineral industries ore grades being mined continue to decrease and costs continue to rise. Elsewhere in the world new high grade mineral deposits are being developed in lands with lower labour costs. For instance, during 1977 Iran is expected to bring into production a copper mine and smelter complex with an annual capacity of 150,000 tonnes. To these developments Canada's mineral industries have available only one major strategic response; more efficient exploration, higher productivity and lower costs through process innovation.

In an uncertain world the Government can help bring innovation about through direct and indirect means. The provision of a stable political environment is essential for mining firms if they are to make rational long term resource commitments in Canada. Recent Government policies created the wrong sort of innovation in Canadian mining. Several firms moved their new mine development activities abroad and INCO, traditionally a nickel company, diversified into secondary manufacturing in the United States.

The results of this study show that at the present time the innovative effort in the Canadian mineral industries is concentrated amongst a small number of large firms. Many small mining firms have no innovative skills whatsoever, even on an informal basis. In fact they appear to innovate only rarely. Consequently, new processes may be restricted for a considerable period to only the large firms who develop it, or their licensees. As was suggested earlier, a technological gap may be developing in which there are a small number of companies with advanced technology and a large number with processes that are not best practice. In a recent instance where several small mines were brought together within the structure of one of Canada's larger mining companys, productivity increases were achieved through rationalisation and process innovation. Apart from the welfare considerations of employees in mines with old technology, there is a risk that small firms may gradually become uneconomic, and that the mineral industries will be even more dominated by a few large ones than at present.

Possibly the Government should assist small and medium sized firms to adopt new processes. These firms provide the competitive challenge to large firms and are a critical sector of the mineral industries. Frequently they occupy "niches" that are too small for the large firms to exploit. Incentives might encourage medium sized firms to increase the range of their innovative activities to include development.

Small firms could be given indirect assistance to innovate, such as special tax exemptions. However, a more positive approach would be to assist the small mines by reducing the uncertainty that is inherent in process innovation. The Government (Federal or Provincial) might provide project management assistance to small mines which are adopting new processes. Research and development services, emphasising development, could be provided by Government laboratories.

A programme of direct Government innovation assistance to smaller mines would have to be taken out to them. Miners are suspicious of Government involvement, and nowadays research and development has to be "sold" as the head of one of Canada's largest industrial research laboratories commented recently.

In a broader perspective, advantages to both the mineral industries and the nation could be derived from a more extensive exploitation of new mining processes. Substantial industries in Sweden, Germany and the United States have developed based on the growth of mining equipment supply firms. These firms are now large and have the resources to compete extensively in foreign markets. In these countries firms,and sometimes Governments,have recognised that small firms cannot compete effectively in international capital equipment markets where the nature of the product requires extensive after sales support. Purchasers of mining equipment demand that suppliers are able to provide efficient and prompt maintenance for their products. A large organization is required if an equipment supply firm is to compete in a large number of foreign markets.

In Canada, the historical evolution of the mining industry has emphasised the role of distributors and branch plant manufacturers of process equipment. These operations have been able to survive periods of low mine starts by either having low overheads or alternative markets. However, Canada now has a large market for mining process equipment, one that is stable enough to provide the domestic sales base for a Canadian owned international mining equipment manufacturer.

Government support for the establishment of this firm would be a strategic move to derive increased revenues, employment and exports from mineral related industries. Imports of mining equipment would probably be reduced. If Canada is to develop successful manufacturing industries, mining equipment, like agricultural equipment, is one of the most obvious opportunities given our mining expertise.

As the research has shown, to be successful this manufacturing firm must create a special relationship with mining companies which would eliminate market related uncertainties in product innovation. One relationship that might be used as a model is that of Bell Canada Ltd., Bell Northern Research Ltd., and Northern Electric Ltd., Bell Northern Research Ltd., being jointly owned, exists to develop, for Bell Canada, new processes which are new products for Northern Electric Ltd. Northern Electric Ltd. derives substantial revenues from sales of new products to other communications companies around the world. A similar arrangement is not inconceivable as being effective in the Canadian mineral industries.

In short, Canadian Governments have a key role to play in ensuring the continued viability of domestic mineral industries. Normative statements about there not being enough innovation in mining are vague and carry no clue as to what is needed. However, it is fact that the industries have identified a number of major process innovations as necessary, but that these are not being worked on. Also, we have seen that many small mining firms lack the capability to undertake significant process innovation. Direct and indirect Government actions can help stimulate innovation as well as enable the exploitation of process equipment innovations in the form of manufactured exports.

7.5 Implications for Future Research

This research has concentrated on only a small group of companies. For these firms in the Canadian mineral industries innovative strategies can be identified which change as they grow in size. Technological strategies have been discussed in previous papers by Quinn[3] and Ansoff and Stewart[4], but they have not been characterised and empirically observed as has been done here. One direction for future research might be to examine whether similar innovative strategies exist in other industries, and what impact they have on firms in those industries.

Process innovation could be an important competitive strategy in other "commodity" industries or in mature industries where the rate of new product development is low. There exists considerable dispute as to which industries have small firms which are innovative and which have large ones that are so; a summary of the issues is presented by Markham.[5] The present research has indicated several factors that may influence this distribution of innovative activities. Chief amongst them are:

1. The cost of process innovation compared to the resources of firms in the industry.

2. The presence of unmeasurable uncertainty in other aspects of the firm's operations.

3. The nature of the relationship between user and supplier of process equipment.

4. The extent to which products can be differentiated.

Recent work by Wilder and Stansell[6] has indicated that research and development outlays by privately owned electric utilities in the United States increase with size of the utility. Electric utilities have several elements of their business in common with mining. Their output is a commodity with no product differentiation. Inputs are energy sources such as coal, oil and nuclear energy which have uncertain futures. Capital equipment costs are high and new processes are probably very costly. Process innovation may well have system-wide effects requiring knowledge of the total process.

Of course, not all industries are alike in their innovative requirements. Some industries have simultaneous need for product and process innovation, others only for product innovation. Mining and electric utilities apparently belong to a third group in which process innovation takes place whilst products remain the same. The three major common characteristics of this group are probably:

1. A product with little or no differentiation from others except on the basis of price.

2. Inputs that are scarce and whose future is uncertain.

3. Processes which are costly, and which determine the firm's ability to compete.

In these industries the performance of research and development may increase with firm size. Process innovation is of too great an importance to be left to process equipment suppliers. Consequently as process users acquire greater resources they increase their internal commitment to process innovation. The present research has shown that the Canadian mineral industries contain firms acting in this manner through the implementation of identifiable innovation strategies. Future research could attempt to extend these findings to other industries.

This research on firms in the Canadian mineral industries has only been concerned with what firms do. Some attempt has been made to explain why they act as they have been found to, but no attempt has been made to measure how successful are firms with particular innovative strategies, or how particular innovative strategies affect the profitability and growth of the mining firm. Additional future research might investigate both these topics. The results of this research suggest two further propositions which might be tested:

Proposition 1:
Firms with integrative innovation strategies will be more successful at acquiring process innovations than firms with other strategies.

Proposition 2:
Firms with active and integrative innovation strategies will benefit economically from their process innovation strategy more than will firms with either defensive or passive strategies.

The first is proposed because, as Wrigley and Morton suggest, successful innovation comes about when the innovative activities are integrated administratively. There will undoubtably be some problem in defining 'success' for such research. However, if innovative strategies are to be evaluated some measure of their success must be developed.

The second is put forward because the firms with either active or integrative strategies will be more successful at implementing the products of process research and development than other firms, and also because they will be able to license the process innovations to other firms.

A final topic for future research would be to investigate the conditions for successful innovation through user-supplier cooperation. There are many instances of successful innovation where user and supplier have co-operated. However, information collected as a by-product of the present work indicates that many formal and informal mechanisms operate in such cases which act to effectively eliminate true market integration and which substitute instead a form of administrative integration.

FOOTNOTES TO CHAPTER VII

1. Abernathy, W.J. and Townsend, P.L., Technology, Productivity and Process Change. Unpublished Working Paper, Harvard University Graduate School of Business Administration, June 1973. Revised June 1974.

2. Quinn, J.B. and Mueller, J.A., "Transferring Research Results to Operations." Harvard Business Review, January-February, 1963.

3. Ibid.

4. Ansoff, I. and Stewart, J.M., "Strategies for a Technology Based Business." Harvard Business Review, November-December 1967.

5. Markham, J.W., "Market Structure, Business Conduct, and Innovation." The American Economic Review, Vol. 55, No. 2, May 1965, pp. 323-332.

6. Wilder, R.P. and Stansell, S.R., "Determinants of research and development activity by electric utilities." The Bell Journal of Economics and Management Science, Vol. 5, No. 2, Autumn 1974, pp. 646-650.

APPENDIX

THE QUESTIONNAIRES

CANADIAN MINING SUPPLY INDUSTRY

QUESTIONNAIRE

SCHOOL OF BUSINESS ADMINISTRATION

THE UNIVERSITY OF WESTERN ONTARIO

Participating Number________________

Date Completed____________________

[ ][ ][ ][ ][ ][ ][ ][ ][ ][ ]

01 02 03 04 05 06 07 08 09 10

If there are any questions that have no response would you indicate in the margin whether the answer is confidential (C), unknown (U), or not applicable (A).

Section I — General Company Data

☐☐☐ C U A

1.1 What were your Company's total sales in the fiscal years 1968 - 1973 inclusive?

1968 $ [ ],[ ][ ][ ],[ ][ ][0],[0][0][0]
11 12 13 14 15 16

1969 $ [ ],[ ][ ][ ],[ ][ ][0],[0][0][0]
17 18 19 20 21 22

1970 $ [ ],[ ][ ][ ],[ ][ ][0],[0][0][0]
23 24 25 26 27 28

1971 $ [ ],[ ][ ][ ],[ ][ ][0],[0][0][0]
29 30 31 32 33 34

1972 $ [ ],[ ][ ][ ],[ ][ ][0],[0][0][0]
35 36 37 38 39 40

1973 $ (est.) [ ],[ ][ ][ ],[ ][ ][0],[0][0][0]
41 42 43 44 45 46

☐☐☐ C U A

2.2 What were your Company's total sales to the mining industry in the fiscal years 1968 - 1973 inclusive?

1968 $ [ ][ ][ ],[ ][ ][0],[0][0][0]
47 48 49 50 51

1969 $ [ ][ ][ ],[ ][ ][0],[0][0][0]
52 53 54 55 56

1970 $ [ ][ ][ ],[ ][ ][0],[0][0][0]
57 58 59 60 61

1971 $ [ ][ ][ ],[ ][ ][0],[0][0][0]
62 63 64 65 66

1972 $ [ ][ ][ ],[ ][ ][0],[0][0][0]
67 68 69 70 71

1973 $ (est.) [ ][ ][ ] , [ ][ ][0] , [0][0][0]
72 73 74 75 76

□□□
C U A

3.3 What was the value of export sales, if any, to the mining industry in other countries in the fiscal years 1968 - 1973 inclusive?

1968 $ [ ][ ][ ] , [ ][ ][0] , [0][0][0]
77 78 79 80 c_{11}

1969 $ [ ][ ][ ] , [ ][ ][0] , [0][0][0]
12 13 14 15 16

1970 $ [ ][ ][ ] , [ ][ ][0] , [0][0][0]
17 18 19 20 21

1971 $ [ ][ ][ ] , [ ][ ][0] , [0][0][0]
22 23 24 25 26

1972 $ [ ][ ][ ] , [ ][ ][0] , [0][0][0]
27 28 29 30 31

1973 $ (est.) [ ][ ][ ] , [ ][ ][0] , [0][0][0]
32 33 34 35 36

□□□
C U A

4.4 How many employees did you have in Canada at December 31, 1973?

37 38 39 40 41
[ ][ ][ ][ ][0]

□□□
C U A

5.5 (a) The effective controlling interest in your company's shares are held in which country?

________________________ [ ][ ]
42 43

(b) The majority of your company shares are held in which country?

________________________ [ ]
44

□□□
C U A

6.6 Is your company affiliated with, or a subsidiary of, another company?

45
[ ] Yes 1 [ ] No 2

If yes, of what nationality is this company?

46 47 48

________________ [| |]

7.7 Which of the following describes the nature of your operation? (as a % of total).

☐☐☐
C U A

(a)	warehouse & distribution (non manufacture)	49	[|]	50
(b)	sales agency (non manufacture)	51	[|]	52
(c)	assembly	53	[|]	54
(d)	manufacture	55	[|]	56
(e)	other ________________	57	[|]	58
			100%	

[|]
59 60

Section II . Company Products

☐☐☐
C U A

1.8 What are the principal products that you sell to the mining industry?

____

____ ☐☐☐

☐☐☐
C U A

2.9 The approximate corresponding price per unit is?

(1)	less than $100.00	☐	(2)	$100.01 – $1,000	☐
(3)	$1,000.01 – $10,000.	☐	(4)	$10,000.01 – $100,000.	☐
(5)	$100,000.01 – $1,000,000	☐	(6)	over $1,000,000.01	☐

☐☐☐

☐☐☐
C U A

3.10 What percentage of sales to the mining industry does each product represent?

	Product type-name	Price	% of Sales
(a)	______ 61 62 63 ☐☐☐	$ ______ 73 ☐	77 78 ☐☐
(b)	______ 64 65 66 ☐☐☐	$ ______ 74 ☐	79 80 ☐☐
(c)	______ 67 68 69 ☐☐☐	$ ______ 75 ☐	11 12 ☐☐
(d)	______ 70 71 72 ☐☐☐	$ ______ 76 ☐	13 14 ☐☐
			100% TOTAL

☐☐☐
C U A

4.11 Please identify one product out of your principal products which you would consider new to the Canadian Market.

______________________________ 15 16 17 ☐☐☐

☐☐☐
C U A

5.12 How long has this product been on the market?

18 19 ☐☐ years

☐☐☐
C U A

6.13 Who are the competitors of this product?

(a) in Canada? ______________________________

______________________________ 20 21 22 23 24 25 26 ☐☐☐☐☐☐☐

(b) Internationally? ____________________

27 28 29 30 31 32 33 [ ][ ][ ][ ][ ][ ][ ]

☐☐☐
C U A

7.14 How was this product developed?

(a) In Canada — by your company 34 ☐ Yes 1 ☐ No 2

by other ____________ 35 36 37 [ ][ ][ ]

(b) Outside of Canada — by your company 38 ☐ Yes 1 ☐ No 2

by other ____________ 39 40 41 [ ][ ][ ]

☐☐☐
C U A

8.15 Does your company sell this product only in Canada?

42 ☐ Yes 1 ☐ No 2

If not, where else? ____________ 43 44 45 [ ][ ][ ]

☐☐☐
C U A

9.16 Is the product manufactured by your company?

(a) In Canada? 46 ☐ Yes 1 ☐ No 2

(b) Outside Canada? ____________ 47 48 49 [ ][ ][ ]

Section III Research & Development Undertaken by your Company

In this section would you guide your responses in accordance with the following definitions. (Taken from Statistics Canada).

RESEARCH & DEVELOPMENT

(a) R&D is investigative work carried out:

- i) to acquire new scientific and technological knowledge,
- ii) to devise and develop new products or processes, or
- iii) to apply newly acquired knowledge in making technically significant improvements to existing products or processes.

(b) For the purposes of this survey, R&D does not include:

- i) market research and sales promotion,
- ii) research in the social sciences,
- iii) operations research, except when required during the development phase of a product or process,
- iv) quality control or routine testing of products and materials,
- v) geological and geophysical surveys, mapping, exploration and similar activities not resulting in scientific or technological advance,
- vi) scientific and technical information except when conducted for the sole or primary purpose of R&D support,
- vii) all activities necessary necessary for commercial production of the new or improved product or process after development is completed.

(c) Research and development may be carried out either by a permanent R&D unit (e.g. R&D division or department, or by a unit generally engaged in any non-R&D activity such as engineering or production. In the first case, the R&D unit may spend part of its time on routine testing or trouble shooting or on some other activities which should not be included in R&D. In the second, consider only the R&D portion of such units' total activity.

Basic Research

This type of research is a generalized search for new knowledge without specific application in mind. It is usually judged on the contributions which it makes to the conceptual development of science.

Applied Research

This type of research is the search for new knowledge to provide a solution to a specific problem which is defined at the outset of the research program. It does not differ radically from basic research in methods or scope, but in motivation.

Development

Development is the use of knowledge derived from research in order to produce new materials, devices, products or to devise new processes, or to improve existing ones. Thus, the design, construction and testing of prototypes, models pilot plants (so long as they are primarily used to acquire experience and gather information necessary to the start-up of production) are part of it. Moreover, development includes those activities required before the setting up of a process or production line and which embody the information gathered from development activities: for example, the preparation of drawings, reports and instructions.

11.27 Has your Canadian Company licensed foreign innovations within the last five years?

☐☐☐
C U A

80 ☐ Yes 1 ☐ No 2

If yes, please describe the type of product and arrangement.

(a) ____________ C_4 ☐☐☐ 11 12 13

(b) ____________ ☐☐☐ 15 16 17

(a), (b)

(1) warehouse ☐

(2) sales agency ☐ ☐ 14

(3) assembly ☐

(4) manufacture ☐

(5) other ☐ ☐ 18

____

12.28 How many qualified scientists and engineers holding at least a B. Sc. or professional designation do you employ in mining research?

☐☐☐
C U A

☐☐☐ 19 20 21

13.29 Do you import innovation from a parent company abroad?

☐☐☐
C U A

22 ☐ Yes 1 ☐ No 2

14.30 Do you receive or have you received any Canadian government assistance in your research and development activities?

☐☐☐
C U A

23 ☐ Yes 1 ☐ No 2

If yes, please state what form ____________________________

____

____________________________ ☐☐ 24 25

15.31 Do you see a greater co-ordinated activity between the supply force and the mining companies in the future?

☐☐☐
C U A

26 ☐ Yes 1 ☐ No 2

16.32 Do you see a greater co-ordinated activity between the supply force and the Canadian government in the future?

☐☐☐
C U A

27 ☐ Yes 1 ☐ No 2

□□□
C U A

17.33 What incentive should the government provide for mining process and equipment innovation in Canada?

____

____

____ □□□
28 29 30

Development ceases and pre-production begins when the work is no longer experimental. Hence, the costs of tooling (design and try out), the costs of construction drawings and manufacturing blueprints and the costs of production start-up are not included in development costs.

Technological Innovation

This is the transformation of a scientifically developed product (process) into a new or improved marketable product (operational process). It covers the work necessary to carry a product from the end of the R&D phase to successful production and sales (e.g. new product marketing, final design engineering, tooling and industrial engineering, manufacturing start-up, patent work, etc.).

1.17 Do you have a research and development department in Canada?

50 ☐ Yes 1 ☐ No 2

2.18 If no, do you have any informal organization concerned with research and development in mining?

51 ☐ Yes 1 ☐ No 2

☐☐☐ C U A

3.19 Do you have a research and development budget for mining products?

52 ☐ Yes 1 ☐ No 2

☐☐☐ C U A

4.20 If yes, how much per annum is budgeted or allocated in general?

$ ☐☐☐☐☐☐☐ 53 54 55 56 57 58 59

☐☐☐ C U A

5.21 What percentage of your budget is allocated to:

(a) basic research ☐☐ 60 61

(b) applied research ☐☐ 62 63

(c) development ☐☐ 64 65

100%

C U A

6.22 How is research and development evaluated?

(a) return on investment 66 ☐ 1

(b) technological development ☐ 2

(c) no formal evaluation ☐ 3

(d) other, please specify ☐ 4

____

______________________ ☐ 5

C U A

7.23 Has your company taken out any patents on mining in the last five years? If so, please state how many.

☐☐ 67 68

C U A

8.24 Have these patents been applied for in other countries?

69 ☐ Yes 1 ☐ No 2

C U A

9.25 Do you consider patents important to your organization?

70
(a) very ☐ 1
(b) moderately ☐ 2
(c) slightly ☐ 3
(d) not at all ☐ 4

C U A

10.26 Have you licensed other organizations to manufacture and/or sell your product developments within the last five years?

71 ☐ Yes 1 ☐ No 2

If yes, please describe the type of product and arrangement.

(a) ______________________ ☐☐☐ 72 73 74

(b) ______________________ ☐☐☐ 76 77 78

(1) warehouse
(2) sales agency
(3) assembly
(4) manufacture
(5) other

____

(a) ☐ 75

(b) ☐ 79

Section IV — Your Company's Relationship with the Mining Industry

☐☐☐ C U A

1.34 Do your mining industry customers ask you to develop new products for them?

(a) Never — 31 ☐ 1

(b) Infrequently (once or twice every decade) — ☐ 2

(c) Occasionally (once per year) — ☐ 3

(d) Fairly often (3 or 4 times per year) — ☐ 4

(e) Very often (once a month or more) — ☐ 5

☐☐☐ C U A

2.35 Do your mining industry customers normally pay development costs?

32 ☐ Yes 1 ☐ No 2

☐☐☐ C U A

3.36 Who do you consider more innovative, the large mining companies or small mining companies?

(a) small — 33 ☐ 1

(b) large — ☐ 2

(c) size not determining factor — ☐ 3

☐☐☐ C U A

4.37 Identify by name those mining companies you consider to be more technologically innovative and advanced.

____

____

____

☐☐ 34 35 ☐☐ 36 37 ☐☐ 38 39 ☐ 40

☐☐☐ C U A

5.38 Do you consider your Canadian company very innovative relative to your competition in Canada?

(a) little — 41 ☐ 1

(b) average — ☐ 2

(c) very — ☐ 3

6.39 To which part of the mining organization are most of your sales made?(in order of importance: 1, 2, 3 and 4).

☐☐☐
C U A

(a) Head Office ☐ 42 to whom?______________ (position) ☐☐☐ 43 44 45

(b) Mine site ☐ 46 to whom?______________ (position) ☐☐☐ 47 48 49

(c) Consultant (Engineer) ☐ 50

(d) Mining Contractor ☐ 51

7.40 Do you try out new product innovations in cooperation with mining companies?

☐☐☐
C U A

52 ☐ Yes 1 ☐ No 2

8.41 For your company what would you estimate is the total cost of bringing a new product to market?

☐☐☐
C U A

(a) under $5,000 53 ☐ 1

(b) $ 5,000 - $ 20,000 ☐ 2

(c) $ 20,000 - $ 50,000 ☐ 3

(d) $ 50,000 - $ 100,000 ☐ 4

(e) $100,000 - $ 500,000 ☐ 5

(f) $500,000 - $1,000,000 ☐ 6

(g) over $1,000,000 ☐ 7

9.42 In response to above question (No. 8), how would these costs be allocated?

☐☐☐
C U A

(a) Research and development 54 ☐ 55
(b) Licensing 56 ☐ 57
(c) Production tooling and manufacture set-up 58 ☐ 59
(d) Marketing 60 ☐ 61

☐☐☐
C U A

10.43 How many new products were developed by your company over the last 5 years?

total number ☐☐ 62 63

number successful ☐☐ 64 65

number failures ☐☐ 66 67

☐☐☐
C U A

11.44 What particular obstacles, if any, does your company encounter in the Canadian mining industry?

____

____

____

☐☐☐ 68 69 70

☐☐☐
C U A

12.45 Do you see substantial opportunities for product innovation in mining industry process equipment in the next 10 years?

____

____

____

☐☐☐ 71 72 73

☐☐☐
C U A

13.46 If yes, how will this affect your own product range?

____

____

____

☐☐☐ 74 75 76

☐☐☐
C U A

14.47 Do you see the mining supply force becoming export oriented or import oriented?

(a) import 77 ☐ 1

(b) export ☐ 2

Please specify why? ____

____

☐☐☐ 78 79 80

CANADIAN MINING INDUSTRY QUESTIONNAIRE

SCHOOL OF BUSINESS ADMINISTRATION
THE UNIVERSITY OF WESTERN ONTARIO

PARTICIPATING NUMBER ____________

DATE COMPLETED ________________

01 02 03 04 05 06 07 08 09 10

If there are any questions that have no response, would you indicate in the margin whether the answer is confidential (C), Unknown (U), or Not Applicable (A).

1.1 What were your Company's total sales in the fiscal years 1968 - 1973 inclusive?

☐ C 1968 $ [| | | | | 0 | 0 | ,0 | 0 | 0] 11 12 13 14 15 — 1971 $ [| | | | | 0 | 0 | ,0 | 0 | 0] 26 27 28 29 30

☐ U 1969 $ [| | | | | 0 | 0 | ,0 | 0 | 0] 16 17 18 19 20 — 1972 $ [| | | | | 0 | 0 | ,0 | 0 | 0] 31 32 33 34 35

☐ A 1970 $ [| | | | | 0 | 0 | ,0 | 0 | 0] 21 22 23 24 25 — 1973 (est.) $ [| | | | | 0 | 0 | ,0 | 0 | 0] 36 37 38 39 40

2.2 What were your Company's revenues from mining operations in the fiscal years 1968 - 1973 inclusive?

☐ C 1968 $ [| | | | | | 0 | ,0 | 0 | 0] 41 42 43 44 45 46 — 1971 $ [| | | | | | 0 | ,0 | 0 | 0] 59 60 61 62 63 64

☐ U 1969 $ [| | | | | | 0 | ,0 | 0 | 0] 47 48 49 50 51 52 — 1972 $ [| | | | | | 0 | ,0 | 0 | 0] 65 66 67 68 69 70

☐ A 1970 $ [| | | | | | 0 | ,0 | 0 | 0] 53 54 55 56 57 58 — 1973 (est.) $ [| | | | | | 0 | ,0 | 0 | 0] 71 72 73 74 75 76

3.3 What were your Company's total net income in the years, 1968 - 1973 inclusive?

☐ C 1968 $ [| | | | | 0 | ,0 | 0 | 0] 77 78 79 80 11 C2 — 1971 $ [| | | | - | 0 | ,0 | 0 | 0] 22 23 24 25 26

☐ U 1969 $ [| | | | | 0 | ,0 | 0 | 0] 12 13 14 15 16 — 1972 $ [| | | | | 0 | ,0 | 0 | 0] 27 28 29 30 31

☐ A 1970 $ [| | | | | 0 | ,0 | 0 | 0] 17 18 19 20 21 — 1973 (est.) $ [| | | | | 0 | ,0 | 0 | 0] 32 33 34 35 36

4.4 How many employees did you have in Canada at December 31, 1973?

☐ ☐ ☐
C U A

[| | | | | 0] 37 38 39 40 41

5.5 At how many Canadian locations do you have mining operations?

☐☐☐ C U A

☐☐ 42 43

6.6 (A) The effective controlling interest in your company's shares are held in which country? ______________________

☐☐☐ C U A

☐☐ 44 45

(B) The majority of your company's shares are held in which country?

____

☐☐☐ C U A

☐ 46

7.7 Is your company effectively controlled by another company?

☐☐☐ C U A

47 ☐ Yes1 ☐ No2

If so, state the company's name and nationality please.

____

☐ 48 ☐ 49 ☐ 50

8.8 What percentage of revenue comes from these operations?

☐☐☐ C U A

(a)	Smelting ______________	51		52
(b)	Refining ______________	53		54
(c)	(Metal) Processing (rolling, drawing, etc.) ______________	55		56
(d)	(Metal) Fabricating ______________			
(e)	Mining Equipment Mfg. ______________	57		58
(f)	Exploration Services ______________	59		60
(g)	Mining ______________	61		62
	(eg. consulting services)	63		64
			100%	

9.9 What are the principal minerals produced by your company?

☐☐☐ C U A

____

____

____

______________________ ☐☐ 65 66 ☐☐ 67 68 ☐☐ 69 70 ☐ 71 ☐ 72

10.10 Does your company have:

(a) A Management services staff (R&D, Purchasing, Sales) located at the mine site?

☐☐☐ C U A

73 ☐ Yes1 ☐ No2

10.10(b) A mining services staff away from the mine site?

☐ ☐ ☐
C U A

i)	only (a)	74 ☐ 1	(at the mine site)
ii)	only (b)	☐ 2	(away from the mine site)
iii)	both (a & b)	☐ 3	

Section II Research & Development Undertaken by your Company

In this section would you guide your responses in accordance with the following definitions. (Taken from Statistics Canada).

RESEARCH & DEVELOPMENT

(a) R&D is investigative work carried out:

i) to acquire new scientific and technological knowledge,
ii) to devise and develop new products or processes, or
iii) to apply newly acquired knowledge in making technically significant improvements to existing products or processes.

(b) For the purposes of this survey, R&D does not include:

i) market research and sales promotion,
ii) research in the social sciences,
iii) operations research, except when required during the development phase of a product or process,
iv) quality control or routine testing of products and materials,
v) geological and geophysical surveys, mapping, exploration and similar activities not resulting in scientific or technological advance,
vi) scientific and technical information except when conducted for the sole or primary purpose of R&D support,
vii) all activities necessary for commercial production of the new or improved product or process after development is completed.

(c) Research and development may be carried out either by a permanent R&D unit (e.g. R&D division or department, or by a unit generally engaged in any non R&D activity such as engineering or production. In the first case, the R&D unit may spend part of its time on routine testing or trouble shooting or on some other activities which should not be included in R&D. In the second, consider only the R&D portion of such units' total activity.

Basic Research

This type of research is a generalized search for new knowledge without specific application in mind. It is usually judged on the contributions which it makes to the conceptual development of science.

Applied Research

This type of research is the search for new knowledge to provide a solution to a specific problem which is defined at the outset of the research program. It does not differ radically from basic research in methods or scope, but in motivation.

Development

Development is the use of knowledge derived from research in order to produce new materials, devices, products or to devise new processes, or to improve existing ones. Thus, the design, construction and testing of prototypes, models, pilot plants (so long as they are primarily used to acquire experience and gather information necessary to the start-up of production) are part of it. Moreover, development includes those activities required before the setting up of a process or production line and which embody the information gathered from development activities; for example, the preparation of drawings, reports and instructions.

Development ceases and pre-production begins when the work is no longer experimental. Hence, the costs of tooling (design and try out), the costs of construction drawings and manufacturing blueprints and the costs of production start-up are not included in development costs.

Technological Innovation

This is the transformation of a scientifically developed product (process) into a new or improved marketable product (operational process). It covers the work necessary to carry a product from the end of the R&D phase to successful production and sales (e.g. new product marketing, final design engineering, tooling and industrial engineering manufacturing startup, papent work, etc.).

☐☐☐ C U A

1.11 Does your Company have a specific research and development program in Canada?

75 ☐ Yes 1 ☐ No 2

☐☐☐ C U A

2.12 If no, do you have any informal organization concerned with research and development in mining?

76 ☐ Yes 1 ☐ No 2

☐☐☐ C U A

3.13 What is your company's annual research and development budget?

$ ☐☐☐☐☐☐☐
77 78 79 80 11 12 13

C3

☐☐☐ C U A

4.14 What is your company's annual budget for exploration?

$ ☐☐☐☐☐☐☐
14 15 16 17 18 19 20

☐☐☐ C U A

5.15 How many qualified scientists and engineers holding at least a B.Sc. or professional designation do you employ in your research activities?

☐☐☐
21 22 23

☐☐☐ C U A

6.16 What percentage of research and development funds are spent on:

(a)	basic research	24		25
(b)	applied research	26		27
(c)	development	28		29

100%

☐☐☐
C U A

7.17 What percentage of research and development funds are spent on:

(a)	product research	30	☐☐	31
(b)	mining research	32	☐☐	33
(c)	milling research	34	☐☐	35
(d)	metal, ore processing research	36	☐☐	37
			100%	

☐☐☐
C U A

8.18 How is research and development evaluated?

(a) return on investment 38 ☐

(b) technological development (products, processes) 39 ☐

(c) no formal evaluation 40 ☐ 1

(d) other, please specify__________________ ☐ 2

☐☐☐
C U A

9.19 Has your company taken out any patents on products, processes, equipment or mining techniques in the last five years? If so, please state how many.

(a) products, equipment etc. 41 ☐☐ 42

(b) processes 43 ☐☐ 44

(c) mining techniques 45 ☐☐ 46

☐☐☐
C U A

10.20 Have these patents been applied for in other countries?

47 ☐ Yes 1 ☐ No 2

☐☐☐
C U A

11.21 Do you consider patents important to your company?

(a) very 48 ☐ 1

(b) moderately ☐ 2

(c) slightly ☐ 3

(d) not at all ☐ 4

☐☐☐
C U A

12.12 Do you license, buy or sell new technology? If so, please indicate how many; type of product or process and arrangement. (During last ten years).

	Number	Licenses Product/Process	Length of Arrangement	
(a) from Canadian Companies	☐☐ 49 50	☐☐☐ 51 52 53	☐☐ 54 55	years
(b) to Canadian Companies	☐☐ 56 57	☐☐☐ 58 59 60	☐☐ 61 62	years

		Number	Licenses Product/Process	Length of Arrangement	
(c)	from Foreign Companies	☐☐ 63 64	☐☐☐ 65 66 67	☐☐ 68 69	years
(d)	to Foreign Companies	☐☐ 70 71	☐☐☐ 72 73 74	☐☐ 75 76	years

☐☐☐
C U A

13.23 Do you import innovation from a parent company abroad?

77 ☐ Yes 1 ☐ No 2

☐☐☐
C U A

14.24 If yes, how is the innovation paid for?

78

(a) royalty ☐ 1

(b) transfer price ☐ 2

(c) absorbed in product cost ☐ 3

(d) Other ☐ 4

☐☐☐
C U A

15.25 Do you obtain research and development funding from:

(a) Federal Government 79 ☐ Yes 1 ☐ No 2 If yes, what source? (for 'a' only) ☐ 80

C4

(b) Provincial Government 11 ☐ Yes 1 ☐ No 2

(c) Associations 12 ☐ Yes 1 ☐ No 2

(d) Other mining companies 13 ☐ Yes 1 ☐ No 2

(e) Parent companies 14 ☐ Yes 1 ☐ No 2

(f) Other 15 ☐ Yes 1 ☐ No 2

☐☐☐
C U A

16.26 Do you enter into joint research and development agreements with:

(a) other mining companies 16 ☐ Yes 1 ☐ No 2

16.26 (b) mining equipment suppliers — 17 ☐ Yes 1 ☐ No 2

(c) government (Federal) — 18 ☐ Yes 1 ☐ No 2

(d) government (Provincial) — 19 ☐ Yes 1 ☐ No 2

(e) universities — 20 ☐ Yes 1 ☐ No 2

(f) other, please specify ________________ — 21 ☐ Yes 1 ☐ No 2

☐☐☐ C U A

17.27 Do you consider research and development to your company:

(a) essential — 22 ☐ 1
(b) significant — ☐ 2
(c) important — ☐ 3
(d) important as other company functions — ☐ 4
(e) unimportant — ☐ 5

☐☐☐ C U A

18.28 Do you have in your company:

(a) cost reduction programs — 23 ☐ Yes 1 ☐ No 2

(b) productivity programs that are not included in research and development budgets? — 24 ☐ Yes 1 ☐ No 2

☐☐☐ C U A

19.29 In general, how much is spent by your company on such programs per year?

$ ☐☐☐☐☐☐☐
25 26 27 28 29 30 31

☐☐☐ C U A

20.30 Do you have full-time personnel on these programs?

32 ☐ Yes 1 ☐ No 2

If yes, how many ☐☐☐☐
33 34 35 36

☐☐☐ C U A

21.31 How are these programs evaluated?

(a) return on investment — 37 ☐ 1

21.31 (b) technological development ☐ 2

(c) other, please specify ______________ ☐ 3

☐☐☐
C U A

22.32 Does your company have an engineering group involved in:

	Size of Group	No. of projects per year	Nature of Projects
(a) Equipment design for mining	38 39 40	41 42 43	44 45
(b) Equipment design for processing	46 47 48	49 50 51	52 53
(c) Product engineering	54 55 56	57 58 59	60 61
(d) interdepartment joint programs (engineering and R & D etc.)	62 63 64	65 66 67	68 69

☐☐☐
C U A

23.33 Are mining equipment innovations important to your company in terms of making ore bodies economic or more profitable?

70 ☐ Yes 1 ☐ No 2

☐☐☐
C U A

24.34 Do you think the government should be involved in mining research:

(a) directly, i.e. carrying out R & D programs 71 ☐

(b) as a partner to mining companies through the provision of funds 72 ☐

(c) indirectly, through the use of tax incentives 73 ☐

(d) not at all 74 ☐

(e) other, please specify 75 ☐

Comments ______________________________

____

____

____

76 77 78 79 80

Section III Your Company's relationship with Mine – Supply Companies

☐ ☐ ☐
C U A

1.35 Do Canadian mining equipment suppliers play a major role in supplying new technology to your company?

76 ☐ Yes 1 ☐ No 2

☐ ☐ ☐
C U A

2.36 Do you rely on mining equipment and process suppliers: ☐ Yes ☐ No

(a) for assistance in research 77 ☐

(b) for assistance in development work 78 ☐

(c) for producing a product from concept form. 79 ☐

☐ ☐ ☐
C U A

3.37 Do you ask mining equipment suppliers to develop new products:

(a) never 80 ☐1

(b) infrequently (once or twice every decade) ☐2

(c) occasionally (once a year ☐3

(d) fairly often (3 to 4 times per year) ☐4

(e) very often (once a month or more) ☐5

☐☐☐
C U A

4.38 Do you normally pay development costs?

C5

11 ☐ Yes 1 ☐ No 2

☐☐☐
C U A

5.39 In general, are mining equipment suppliers in Canada willing to develop new products for your company?

12 ☐ Yes 1 ☐ No 2

☐☐☐
C U A

6.40 Who do you consider more innovative, large mining supply companies or small mining supply companies?

(a) large 13 ☐1

(b) small ☐2

(c) size not determining factor ☐3

☐☐☐
C U A

7.41 Please list the names of suppliers you consider to be more technologically innovative and advanced.

☐☐ 14 15 ☐☐ 16 17 ☐☐ 18 19 ☐ 20

□□□ C U A

8.42 Which of the following do you perceive to be the most effective in applying and developing new technology? - a supplier who is primarily:

(a) warehouse & distribution (non-manufacture) 21 □ 1

(b) sales agency (non-manufacture) □ 2

(c) assembly □ 3

(d) manufacture □ 4

(e) other, specify please ________________ □ 5

□□□ C U A

9.43 Do you consider your company very innovative relative to others in the mining industry?

(a) not very 22 □ 1

(b) average □ 2

(c) very □ 3

□□□ C U A

10.44 What do you consider to be the most significant technological innovation or advance in your company's last 10 years of operation?

____

____

____

____

□□□□ 23 24 25 26   [M] 1   [P] 2   [Pr] 3

27

□□□ C U A

11.45 How was that innovation attained?

(a) developed by your company 28 □

(b) developed by another 29 □

(c) dollar cost to market stage $ □□□□□□□□□ 30 31 32 33 34 35 36 37 38

(d) major industry advance 39 □

□□□ C U A

12.46 Do you work with:

(a) mining contractors □ $ ____________ □□□ 40 41 42

(b) consulting engineers □ $ ____________ □□□ 43 44 45

Please indicate the dollar amount spent with either group in 1972.

□□□ C U A

13.47 What particular obstacles, if any, does your company encounter in the Canadian Mine-Supply Force?

____

____

□□□□ 46 47 48 49

☐☐☐
C U A

14.48 Do you see substantial opportunities for product innovation in mining industry process equipment in the next ten years? If yes, please state in general terms the opportunity and the resulting affect on your operation.

____

____

____

____

☐☐☐
50 51 52

☐☐☐
C U A

15.49 Do you see the Canadian mining supply force becoming export-oriented or import-oriented?

(a) export 53 ☐ 1

(b) import ☐ 2

Please specify why? ________________________________

____

____

☐☐☐
54 55 56

☐☐☐
C U A

16.(a)50 Do you see a greater co-ordinated activity between the supply force and the mining companies.

57 ☐ Yes 1 ☐ No 2

(b) Do you see a greater co-ordinated activity between the government and the mining companies?

58 ☐ Yes 1 ☐ No 2

What benefits do you see in any co-ordinated activity?

____

____

____

____

____

____

☐☐☐
59 60 61

☐ ☐ ☐
C U A

17.51 What would you estimate is the total cost in general of a major mining process innovation?

(a)	under $5,000	☐ 1	62
(b)	5,000 - 20,000	☐ 2	
(c)	20,000 - 50,000	☐ 3	
(d)	50,000 - 100,000	☐ 4	
(e)	100,000 - 500,000	☐ 5	
(f)	500,000 - 1,000,000	☐ 6	
(g)	1,000,000 - 5,000,000	☐ 7	
(h)	over $5,000,000	☐ 8	

☐ ☐ ☐
C U A

18.52 In your opinion, what are the major innovations that are currently required in your company's sector of the mining industry?

1. ______________________________ ☐☐☐ 63 64 65

2. ______________________________ ☐☐☐ 66 67 68

3. ______________________________ ☐☐☐ 69 70 71

BIBLIOGRAPHY

Abernathy, W. J. and Townsend, P. L., *Technology, Productivity and Process Change.* Unpublished Working Paper, Harvard University Graduate School of Business Administration, June 1973. Revised June 1974.

Ansoff, I. and Stewart, J. M., "Strategies for Technology Based Business": *Harvard Business Review,* Nov.-Dec. 1967.

Boone, A. E., "Canadian Mining in the Seventies," *The Canadian Mining and Metallurgical Bulletin:* Montreal, August, 1970.

Bright, J. R., *A Guide to Practical Technological Forecasting:* New York, Prentice-Hall Inc., 1973.

The Canadian Minerals Yearbook, Department of Energy Mines and Resources, Queen's Printer, Ottawa, 1973.

The Canadian Mining Manual, National Business Publications Limited, Montreal, 1973.

Chandler, A. D., *Strategy and Structure:* Cambridge, Mass., M.I.T. Press, 1962.

Chou, Ya-lun, *Statistical Analysis:* New York, Holt, Rinehart and Winston Inc., 1969.

Cominco Ltd., *Annual Report.* Vancouver, 1973.

Corporations and Labour Unions Returns Act: Ottawa, Statistics Canada, 1973.

Dawson, J., *Productivity Change in the Canadian Mining Industries.* Study Number 20, Economic Council of Canada, 1971.

The Financial Post Survey of Mines, The Financial Post, Toronto, 1973.

Hedlin Menzies and Associates Ltd., *Thompson Manitoba: A Historical Impact Analysis of Resource Development:* Toronto, 1970.

"Inco, a Giant Learns to Compete," *Fortune*, Vol. XCI, No. 1, January, 1975.

Hudson Bay Mining and Smelting Company Ltd., *Annual Report:* Toronto, 1973.

Knight, F., *Risk, Uncertainty and Profit:* Reprinted, New York, Harper and Row, Publishers, Inc., 1965.

Little, B., *New Product Information Processing: A Descriptive Study of Product Innovation in the Machine Tool Industry.* Unpublished Doctoral Dissertation; Cambridge, Mass., Graduate School of Business Administration, Harvard University, 1967.

Markham, J. W., "Market Structure, Business Conduct, and Innovation," *The American Economic Review*, Vol. 55, No. 2, May 1965, pp. 323-332.

Mazlish, B., *An Enquiry into the Causes of the Wealth of Nations, Representative Selections:* Indianapolis, The Bobbs-Merrill Company Inc., 1961.

"Metals Review," *The Northern Miner*, Vol. 60, No. 47, February 6, 1975.

Morton, J. A., *Organizing for Innovation:* New York, McGraw-Hill Book Company, 1971.

OECD, Gaps in Technology, Paris, 1969.

Olsen, R. P., *Sources of Process Innovation in the Textile Industry.* Unpublished Doctoral Dissertation: Cambridge, Mass., Graduate School of Business Administration, Harvard University, 1967.

Quinn, J. B. and Mueller, J. A., "Transferring Research Results to Operations," *Harvard Business Review*, January-February, 1963.

Report of the Mining Sub-Committee, The National Advisory Committee on Mining and Metallurgical Research, Ottawa, 1973.

Reynolds, J. W., "Research and Technical Development in a Mining Operation," *The Canadian Mining and Metallurgical Bulletin:* Montreal, April, 1970.

Richardson, P. R., and Leenders, M. R., "A Canadian Strategy for Exploiting Mining Technology," *Canadian Mining Journal*, issue of July, 1974.

Richardson, P. R., and Leenders, M. R., Doucet, C., and Kuhlmann, R., *The Role of Innovation in the Mining and Mining Supply Industries*. A Report prepared for the Mineral Resources Branch of the Department of Energy, Mines and Resources; London, Ontario, July, 1974.

Stigler, G. J., "The Division of Labour is Limited by the Extent of the Market," *Journal of Political Economy*, Vol. LIX, No. 3 (June 1951).

Stigler, G. J., "The Organization of Industry," Homewood, Illinois, Richard D. Irwin, Inc., 1968.

Stinchcombe, A., "Social Structure and Organizations," in J. G. March: *Handbook of Organizations*, Rand McNally and Co., Chicago, 1965.

The Story of Hudson Bay Mining and Smelting Co. Ltd., The Hudson Bay Mining and Smelting Co. Limited, Flin Flon, Manitoba, 1972.

Watkins, M. H., "A Staple Theory of Economic Growth," *The Canadian Journal of Economics and Political Science*, Volume XXIX, No. 2, May, 1963, pp. 141-158.

Wilder, R. P. and Stansell, S. R., "Determinants of research and development activity by electric utilities," *The Bell Journal of Economics and Management Science*, Vol. 5, No. 2, Autumn 1974, pp. 646-650.

Wrigley, L., *R/D and Production: Model Predicting Relationship in Various Economic States*, unpublished paper: School of Business Administration, The University of Western Ontario, 1973.

Industry, Trade and Commerce | Industrie et Commerce

TECHNOLOGICAL INNOVATION STUDIES PROGRAM

PROGRAMME DES ÉTUDES SUR LES INNOVATIONS TECHNIQUES

REPORTS/RAPPORTS

	AUTHOR(S)/AUTEUR(S)	UNIVERSITY/UNIVERSITÉ	REPORT TITLE/TITRE DE L'OUVRAGE
1.	I.A. Litvak C.J. Maule	Department of Economics, Carleton University.	Canadian Entrepreneurship: A Study of Small Newly Established Firms. (October 1971)
2.	Harold Crookell	School of Business Administration, University of Western Ontario.	The Transmission of Technology Across National Boundaries. (February 1973)
3.	R.M. Knight	School of Business Administration, University of Western Ontario.	A Study of Venture Capital Financing in Canada. (June 1973)
4.	Blair Little R.G. Cooper R.A. More	School of Business Administration, University of Western Ontario.	The Assessment of Markets for the Development of New Industrial Products in Canada. (December 1971)
5.	K.R. MacCrimmon W.T. Stanbury J. Bassler	Faculty of Commerce and Business Administration, University of British Columbia.	Risk Attitudes of U.S. and Canadian Top Managers. (September 1973)
6.	James C.T. Mao	Faculty of Commerce and Business Administration, University of British Columbia.	Computer Assisted Cash Management in a Technology-Oriented Firm. (March 1973)

Ottawa, Canada
K1A 0H5

7. J.W.C. Tomlinson	Faculty of Commerce and Business Administration, University of British Colombia.	Foreign Trade and Investment Decisions of Canadian Companies. (March 1973)
8. Gérard Garnier	Faculty of Management University of Sherbrooke.	Characteristics and Problems of Small and Medium Exporting Firms in the Quebec Manufacturing Sector with Special Emphasis on Those Using Advanced Production Techniques. (August 1974)
9. I.A. Litvak C.J. Maule	Department of Economics, Carleton University.	A Study of Successful Technical Entrepreneurs in Canada. (September 1972)
10. M.R. Hecht J.P. Siegel	Faculty of Management Studies, University of Toronto.	A Study of Manufacturing Firms in Canada: With Special Emphasis on Small and Medium Sized Firms. (December 1973)
11. Blair Little	School of Business Administration, University of Western Ontario.	The Development of New Industrial Products in Canada. A Summary Report of Preliminary Results, Phase 1. (April 1972)
12. A.R. Wood J.R.M. Gordon R.P. Gillin	School of Business Administration, University of Western Ontario.	Comparative Managerial Problems in Early Versus Later Adoption of Innovative Manufacturing Technologies: Six Case Studies. (February 1973)
13. S. Globerman	Faculty of Administrative Studies, York University.	Technological Diffusion in Canadian Manufacturing Industries. (April 1974)
14. M. James Dunn Boyd M. Harnden P. Michael Maher	Faculty of Business Administration and Commerce, University of Alberta.	An Investigation Into the Climate for Technological Innovation in Canada. (May 1974)

15. I.A. Litvak C.J. Maule	Department of Economics, Carleton University.	Climate for Entrepreneurs: A Comparative Study. (January 1974)
16. J. Robidoux Gérard Garnier	Faculté d'administration, Université de Sherbrooke.	Factors of Success and Weakness Affecting Small and Medium-Sized Manufacturing Businesses in Quebec, Particularly those Businesses Using Advanced Production Techniques. (December 1973) Facteurs de Succès et Faiblesses des Petites et Moyennes Entreprises Manufacturières au Québec, Spécialement des Entreprises Utilisant des Techniques de Production Avancées. (décembre 1973)
17. I. Vertinsky K. Hartley	Faculty of Commerce and Business Administration, University of British Columbia.	Project Selection in Monolithic Organizations. (August 1974)
18. Jean Robidoux	Faculté d'administration, Université de Sherbrooke.	Analytical Study of Significant Traits Observed Among a Particular Group of Inventors in Quebec. (August 1974) Etude Analytique de Traits Significatifs Observés Chez un Groupe Particulier d'Inventeurs au Québec. (août 1974)
19. Blair Little	School of Business Administration, University of Western Ontario.	Risks in New Product Development. (June 1972)
20. Blair Little R.G. Cooper	School of Business Administration, University of Western Ontario.	Marketing Research Expenditures: A Descriptive Model. (November 1973)

21. Blair Little	School of Business Administration, University of Western Ontario.	Wrecking Ground for Innovation. (February 1973)
22. J.W.C. Tomlinson	Faculty of Commerce and Business Administration, University of British Columbia.	Foreign Trade and Investment Decisions of European Companies. (June 1974)
23. Blair Little	School of Business Administration, University of Western Ontario.	The Role of Government in Assisting New Product Development. (March 1974)
24. R.G. Cooper	Faculty of Management, McGill University.	Why New Industrial Products Fail. (January 1975)
25. M.E. Charles D. MacKay	The C.E.R.C.L. Foundation 200 College Street, Toronto, Ontario M5S 1A4	Case Studies of Industrial Innovation in Canada. (February 1975)
26. M.R. Hecht	Faculty of Management Studies, University of Toronto.	A Study of Manufacturing Firms in Canada: With Emphasis on Education of Senior Officers, Types of Organization and Success. (March 1975)
27. I.A. Litvak C.J. Maule	Department of Economics, Carleton University.	Policies and Programmes for the Promotion of Technological Entrepreneurship in the U.S. and U.K.: Perspectives for Canada. (May 1975)
28. R.R. Britney E.F.P. Newson	School of Business Administration, University of Western Ontario.	The Canadian Production/Operations Management Environment: An Audit. (April 1975)
29. R.F. Morrison P.J. Halpern	Faculty of Management Studies, University of Toronto.	Innovation in Forest Harvesting by Forest Products Industries. (May 1975)

30. J.C.T. Mao	Faculty of Commerce and Business Administration, University of British Columbia.	Venture Capital Financing for Technologically-Oriented Firms. (December 1974)
31. J.W.C. Tomlinson C.S. Willie	Faculty of Commerce and Business Administration, University of British Columbia.	Guide to the Pacific Rim Trade and Economic Data Base. (September 1975)
32. D.A.Ondrack	Faculty of Management Studies, University of Toronto.	Foreign Ownership and Technological Innovation in Canada: A Study of the Industrial Machinery Sector of Industry. (July 1975)
33. James C.T. Mao	Faculty of Commerce and Business Administration, University of British Columbia.	Lease Financing for Technology-Oriented Firms. (July 1975)
34. John A. Watson	Faculty of Business Administration and Commerce, University of Alberta.	A Study of Some Variables Relating to Technological Innovation in Canada. (June 1975)
35. Gary A. Sheehan Donald H. Thain Ian Spencer	School of Business Administration, University of Western Ontario.	The Relationships of Long Range Strategic Planning to Firm Size and to Firm Growth (Ph.D. Thesis). (August 1975)
36. John P. Killing	School of Business Administration, University of Western Ontario.	Manufacturing Under License in Canada (Ph.D. Thesis). (February 1975)
37. Peter R. Richardson	School of Business Administration, University of Western Ontario.	The Acquisition of New Process Technology by Firms in the Candian Mineral Industries (Ph.D. Thesis). (April 1975)

38. Steven Globerman	Faculty of Administrative Studies, York University.	Sources of R&D Funding and Industrial Growth in Canada. (August 1975)
39. R.G. Cooper	Faculty of Management, McGill University.	Winning the New Product Game. (June 1976)
40. Peter Hanel	Department of Economics, University of Sherbrooke.	The Relationship Existing Between the R&D Activity of Canadian Manufacturing Industries and Their Performance in the International Market. (August 1976)
41. Albert R. Wood Richard J. Elgie	School of Business Administration, University of Western Ontario.	Early Adoption of Manufacturing Innovation. (1976)
42. Robert G. Cooper	Faculty of Management, McGill University.	The Causes of Commercial Failure of New Industrial Products. (October 1977)
43. James T. Goode	Department of Commerce and Business Administration. University of British Columbia	Japan's Postwar Experience With Technology Transfer. (December 1975)
44. Robert Knoop Alexander Sanders	Department of Management, Concordia University.	Furniture Industry: Attitudes Towards Exporting. (May 1978)
45. Stephen G. Peitchinis	Department of Economics, University of Calgary.	The Effect of Technological Changes on Educational and Skill Requirements of Industry. (September 1978)
46. Christian Marfels	Department of Economics, Dalhousie University.	Structural Aspects of Small Business in the Canadian Economy. (May 1978)

47.	J.W. Tomlinson M. Thompson S.M. Hills R.W. Wright	Faculty of Commerce and Business Administration, University of British Columbia.	Study of Canadian Joint Ventures Japan - 1977 Mexico - 1977 Venezuela and Columbia - 1978 Brazil - 1979
48.	Joseph Chicha Pierre-André Julien	Département d'administration et d'économique. Université du Québec.	Les Stratégies de PME et Leur Adaptation au Changement (Interim Report). (Avril 1978)
49.	Ilan Vertinsky S.L. Schwartz	Faculty of Commerce and Business Administration, University of British Columbia.	Assessment of R&D Project Evaluation and Selection Procedures. (1977)
50.	K.C. Dhawan L. Kryzanowski	Faculty of Commerce and Administration Concordia University Montreal, Quebec	Export Consortia: A Canadian Study. (November 1978) Available at 15.00/copy Send all orders payable to: Dekemco Ltd. Box 87 Postal Station H, Montreal, Quebec H3G 2K5
51.	I.A. Litvak C.J. Maule	York University Carleton University	Direct Investment in the United States by Small and Medium Sized Canadian Firms. (November 1978)
52.	R.M. Knight J.C. Lemon	School of Business Administration, University of Western Ontario.	A Study of Small and Medium Sized Canadian Technology Based Companies. (September 1978)
53.	M.J.C. Martin J.H. Scheilbelhut R. Clements	School of Business Administration, Dalhousie University.	Transfer of Technology from Government Laboratories to Industry. (November 1978)

54. J. Robidoux	Faculty of Administration, University of Sherbrooke.	Study of the Snowmobile Industry in Canada and the Role that Technological Innovation has Played in Its Economic Performance. (English summary only). Facteurs de Croissance de l'Indstrie Canadienne de la Motoneige (1959-1978).
55. R.A. More	School of Business Administration, University of Western Ontario.	Development of New Industrial Products: Sensitivity of Risk to Incentives. (January 1979)
56. Rein Peterson	Faculty of Administrative Studies, York University.	A Study of the Problems Brought to the Attention of the Business Student Consulting Teams Sponsored by the Ontario Government's Small Business Assistance Programme. (February 1979)
57. Robert G. Cooper	Faculty of Management, McGill University.	Project NEWPROD: .A Screening Model .The Dimensions .Identifying Success. (June 1979)
58. George F. Farris	Faculty of Administrative Studies, York University.	Comments on the Course: Management of Creativity and Innovation. (February 1979)
59. J. Graham Smith	Faculty of Management McGill University.	The Renewable Energy Business Sector in Canada: Economic Prospects and Federal Government Initiatives. (May 1979)
60. J.W.C. Tomlinson	Faculty of Commerce & Business Administration University of British Columbia.	Cross Impact Simulation of the Joint Venture Process in Mexico. (December 1978)
61. Robert H. Grasley Jerry D. Dermer	Faculty of Administrative Studies York University. Faculty of Management Studies University of Toronto.	The Status of Innovation in the Strategies of Larger Canadian Corporations. (March 1979)

62. Z.M. Kubinski	Department of Economics University of Calgary	The Small Firm in the Albertan Oil and Gas Industry. (February 1979)
63. Don S. Scott R.M. Blair	Faculty of Engineering University of Waterloo	The Technical Entrepreneur. Available from the authors. (May 1979)
64. Harvey F. Kolodny	Faculty of Management Studies University of Toronto	Sociotechnical Study of Productivity and Social Organization in Mechanical Harvesting Operations in the Canadian Woodlands. (May 1979)
65. Richard T. Barth	Faculty of Commerce and Business Administration. University of British Columbia	A Directory of Research on Research. (May 1979)
66. W. Ed. McMullan	Faculty of Management University of Calgary	Development of a Course on Innovation and Entrepreneurship. (September 1979)

Veuillez faire parvenir votre demande à PEIT:
Please forward your request for TISP reports to:

Program Manager,
Technological Innovation Studies Program,
Technology Branch,
Department of Industry, Trade and Commerce,
235 Queen Street,
Ottawa, Ontario CANADA
K1A OH5