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**AN EXAMINATION OF THE DECISION MAKING PROCESS
IN AMT INVESTMENT DECISIONS**

by

Steve C. K. Loo, B.Comm. (Honours)

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements for the degree of
Master of Management Studies

School of Business
Carleton University
Ottawa, Ontario

March 16, 1987

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"An Examination of the Decision Making Process
in AMT Investment Decisions"

submitted by Steve C. K. Loo, B. Comm. (Honours)
in partial fulfilment of the requirements for
the degree of Master of Management Studies

A handwritten signature in dark ink, appearing to read "K. Loo", is written over a horizontal line.

Thesis Supervisor

A handwritten signature in dark ink, appearing to read "J. Smith", is written over a horizontal line.

Director, School of Business

Carleton University

April 13, 1987

ABSTRACT

This study surveys the current trends and patterns in adopting Advanced Manufacturing Technologies (AMTs) in Canada, examines the decision making processes of the twenty-two Canadian companies which have invested in AMTs, and investigates the validity of four research assumptions frequently cited in the literature concerning AMT investment decisions. These assumptions are the labour cost assumption, flexibility assumption, status quo assumption, and the role of capital budgeting techniques assumption. Results from the survey of secondary data, indicate that Canada is slower to adopt AMTs than other industrialized nations. From the interview results, a general model and five specific models are devised to explain the AMT decision making process. Combining the survey and interview results, it is found that the research assumptions are too general in nature. In order to have practical significance, these assumptions must be more specific towards a particular type of technology and a particular group of firms.

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LIST OF ABBREVIATIONS

AMT	Advanced Manufacturing Technology (plural, AMTs)
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CAD/CAM	Computer-Aided Design and Manufacturing
CBT	Capital Budgeting Technique (plural, CBTs)
CIM	Computer Integrated Manufacturing
DCF	Discounted Cash Flow
FMS	Flexible Manufacturing Systems
IRDP	Industrial and Regional Development Program
IRR	Internal Rate of Return
JIT	Just In Time
MRP	Material Requirement Planning
NPV	Net Present Value
ORC	Ontario Robotic Centre
ROI	Return On Investment

1. INTRODUCTION

Increasingly Advanced Manufacturing Technologies (AMTs), such as robots and computer-aided design and manufacturing, are being recognized as important means of improving productivity which is crucial to the survival of Canadian manufacturing industries. Lags in productivity will serve to regenerate both inflation and unemployment, problems that have stricken the industrialized nations in the early 80's.

The impacts of AMTs are significant due to their inherent characteristics. AMTs differ from the traditional production technology mainly by their ability to mass produce diverse products and the flexibility of changing from one product design to another quickly. Because of these characteristics, the investment in AMTs can be considered a strategic decision to increase the firm's ability to respond to the changing market situation faster, with better products. Not only do AMTs generate benefits to those firms who invest in them, but they also create valuable benefits for the rest of the economy.¹ For example, AMTs generate new design and production know-how that stimulate innovation in a variety of industries, such as automotive and electrical industries.

This implies that countries that have a leading edge in development and use of AMTs will become more competitive in a variety of industries. Consequently, the survival of Canadian industries, in this growing internationalization of markets, hinges upon its ability to adopt the new technologies.

A cursory examination of the adoption of AMTs in Canada reveals that Canada is lagging behind other industrialized nations in the adoption of AMTs. Many researchers blame this on decision makers' over-reliance on the capital budgeting techniques like discounted cashflow methods, payback period and return on investment calculations as

the criteria in evaluation of AMT investment.

Discounted cash flow methods of evaluating capital investments started to become important managerial techniques for making capital budgeting decisions in 1951.² Thirty-six years have elapsed and these discounted cash flow methods, along with the payback period and return on investment, are still the backbone of today's corporate capital budgeting techniques.

In a financially and technologically stable environment, emphasis on these short-term criteria may lead to the highest profits. However, in this competitive environment where foreign countries have been investing aggressively in manufacturing facilities and technology, the emphasis on short-term performance will result in neglecting long-term capital investments which are critical for future survival. The use of these short-term criteria in evaluating capital investment, such as AMTs that are essential for long-term survival, is unappreciated by both academicians, such as Kaplan(1983), and practitioners, such as Emerson(1985).

As Emerson puts it, "to an economy which has been driven by the payback period and ROI calculations ... we have to put aside these rules and guidelines [payback period and ROI] ... and must look for alternate ways to 'justify' the [automation] systems. (1985:28). Also, Chitale felt that, "the pressures for short-term return on investment has pushed several U.S. firms to either give up manufacturing some product lines or move overseas in the hope of benefiting from lower labour costs and subsidies. The effect of this strategy, however, is becoming more and more clear. A portion of every manufacturing dollar spent outside the firm nurtures the vendor, creates his manufacturing assets and supports his fixed costs. This vendor could be your future competitor. In many high-tech businesses, loss of manufacturing strength could also mean eventual loss of R&D product technology leadership"(1986:12).

Many researchers attribute the slow adoption of AMTs to the inability of managers to justify these technologies using capital budgeting techniques. To help managers to properly justify the AMTs, researchers have tried to identify those unique AMT characteristics (most of them are non-quantifiable and strategical) that are not measured by the capital budgeting techniques, and to build evaluation models so that decision makers can use them to evaluate AMTs.

In the process of building these models, there has not been enough study and understanding of the actual AMT decision making process used by the industry. A number of important assumptions related to the financial justification process are made. In addition to the belief that the use of capital budgeting techniques is a major barrier to the adoption of AMTs, researchers assume that managers' put too much emphasis on labour cost savings and too little emphasis on flexibility in the justification of AMTs. Also, they assume that managers always assume business will continue as usual. These research assumptions are doubtful and unsubstantiated. To better understand the actual financial justification process used in the industry, and to substantiate or dispute these evaluation models, there is a need to investigate the appropriateness of these research assumptions.

Moreover, in order to identify the actual underlying causes of slow AMT adoption in Canada, the narrow focus on the financial justification process is not sufficient. It is essential to look at the entire decision making process since the biases against AMTs may be implanted earlier in the decision making process and surfaced in the justification process. Therefore, the narrow focus on financial justification process may only lead to the identification of symptoms but not the real causes of the problem of slow AMT adoption.

The purpose of this study, therefore, is twofold:

1. to verify the validity of the above research assumptions in investment decisions of AMT; and
2. to gain a better understanding of the entire decision making process of AMT investment.

These two points are inter-related. Verification of the research assumptions provide insights into the understanding of the decision making process, and the study of the decision making process leads to the formation of evidence for and against these research assumptions.

To verify the validity of these assumptions, it is important to know why they are made specifically towards the investment in AMTs but not towards the traditional capital equipment. In other words, the unique characteristics that make AMTs different from the traditional capital equipment have to be identified. For both purposes, it is important to study how AMT decisions are made by the decision makers in the industry. Rather than relying solely on the literature, it is necessary to interview top executives of companies that have made AMT investment decisions.

A survey of the companies that are using AMTs will provide a picture of the specific characteristics of these firms that using AMTs. This will then be used as a basis for the selection of companies as samples for the study, through interviews, of their AMT decision making process and for the analysis of these interview results.

Given the nature of this study, only Ontario companies that have invested in AMTs will be selected for interviews. Although the results of this study are limited to one geographic region of Canada, the study does provide an important snapshot of the entire Canadian situation, since Ontario produces over half of the country's manufacturing goods, and has more robots, CAD/CAM, and FMS installations than all

other provinces combined. The selection of companies that have invested in AMTs may create some biases, since companies that have examined the possibility of investing in AMTs but rejected them are ignored. However, it would be very difficult to identify such companies.

In order to understand the AMT decision making process, it is important to know its general patterns and what are the commonalities and differences among these patterns.

The verification of the research assumptions also requires an indepth understanding of the rationale behind these assumptions. Through the analysis of the interview data, the appropriateness of these research assumptions can then be established. Whether they are appropriate or not, the analysis will provide underlying reasons to explain why they are appropriate or why they are not.

Therefore, the specific research objectives of the study are:

1. to investigate the unique characteristics of AMTs;
2. to survey the trends and patterns of AMT adoption in Canada;
3. to find out the patterns of the AMT decision making process;
4. to extract, understand, and examine the appropriateness of some critical financial research assumptions with respect to the AMT evaluation process; and
5. to present recommendations as to the appropriateness of the aforementioned research assumptions and the rationale behind these assumptions.

The organization of the rest of the thesis is described below. Section 2 defines and describes the AMTs. It is hoped that this will provide a basic understanding of a highly sophisticated technical subject. Furthermore, the specific common

characteristics of AMTs which make them different from the traditional technologies are also discussed. These will provide some insights as to why they are so important to the future survival of Canadian industries.

Section 3 reviews the literature related to the adoption of AMTs in Canada and the various justification problems of AMTs. The different viewpoints of the AMT investment problems and the current research direction are summarized.

Section 4 extracts four critical financial justification assumptions which are usually made by researchers in study of AMT investment evaluation procedures. This section also discusses the importance and the relevance of these assumptions and explains why they are doubtful and why their validities need to be studied. In addition, each research assumption is formulated into a research question to facilitate the research design explained in the following section.

Section 5 then outlines the steps of the procedural analysis to validate the above research questions. A preliminary study aimed at uncovering the patterns and trends of AMT applications in Canada, in particular the characteristics of the firms that have AMT investments, is conducted. This not only provides a general picture of AMT adoption in Canada but most importantly it also acts as an information source for the selection of sample. This section also presents the methodology of studying the four research questions. Basically, the methodology outlines the procedures for conducting a series of interviews with top executives who are involved in the AMT investment evaluation process. The specific statistical procedures to test the hypotheses that are derived from the research questions, and other analytical techniques that are used to analyze the results obtained from the interviews, are also discussed in this section.

Section 6 presents the findings of the preliminary stage. Tables, figures, and charts, wherever appropriate, are used to provide a general picture of how AMTs are

used in Canada by sector of the economy, type of manufacturing, size of firms etc. Also, Canada is compared with other industrialized nations in terms of AMT applications.

In Section 7, a detailed description of the firms that were interviewed is given. Firm specific attributes like sales, number of employees and cost of investment among others are listed to provide a better understanding of the sample firms.

Based on the interview results, the AMT decision making process is thoroughly studied in Section 8. First, factors impacting the AMT investment decisions are uncovered. Second, the AMT decision making process is decomposed into several stages to aid our understanding of the complex process. The decomposition then helps to derive a general model which can be used to explain all the decision making processes of the firms in the sample. Finally, five specific models are developed to describe the different patterns of these decisions.

In Section 9, the four research assumptions extracted in Section 4 are carefully examined. Hypothesis testing is employed to determine the validity of these research questions. Analysis of qualitative data from the interview is then used to explain the results of the statistical tests. Also, the AMT literature's criticisms are carefully analyzed to see whether they are correct in the Canadian context. Through this investigation, many insights on the decision making processes, especially the evaluation procedures, of the firms, can be gained.

Finally, discussion and conclusions are presented in Section 10. Before summarizing the contribution of the study, this section acknowledges its biases and limitations. The validity of the research assumptions and the practicality of the evaluation models are then discussed. Finally, suggestions to decision makers in the industry to correct the bias against AMT investment in the decision making process and some future research directions are suggested.

2. THE ADVANCED MANUFACTURING TECHNOLOGIES

Theorist John Naisbitt, author of "Megatrends," stated boldly that North America is being transformed from an industrial society to an information society -- that industrial companies are, in fact, on the way out. The notion of productivity and flexibility as being key factors in industrial survival is pervasive in corporate strategic thinking. These two key factors become more crucial as the freer trade negotiations between Canada and the U.S. are in progress. The importance of and the opportunity provided by the American market are tremendous.³

To understand how Canadian manufacturers can cope with the changing needs of the society and how they can strive for success in the growing competition in the domestic and foreign markets, it is important to know what kinds of Advanced Manufacturing Technologies are available and how Canadian manufacturers are using these AMTs to their advantages.

A number of advanced manufacturing technologies have come up since early 70's. Most of these technologies have taken advantage of the rapid growth of the computer technology. Reduction of computer hardware cost, increase in computing capability, and the availability of sophisticated software have contributed to the rapid growth of the AMTs. As a result, managers of manufacturing firms are being suddenly confronted with an array of new systems to improve production efficiency.

Different researchers may define the term "AMTs" differently. However, many of them considered Robot, Computer-Aided Design and Manufacturing (CAD/CAM), and Flexible Manufacturing Systems(FMS) as Advanced Manufacturing Technologies.⁴ It is because they have some similar characteristics, notably the ability to improve productivity and flexibility, that make them to be the hot issues of the eighties. Although AMTs can also include other computerized manufacturing

techniques, the three mentioned above are the most common ones. Appendix 1 provides detailed definitions of these three types of production technologies.

These three AMTs are then discussed in turn in the following subsections. For each type, a general accepted definition and a description with respect to its function are presented. Section 2.4 then summarizes the common characteristics of these technologies.

2.1. Programmable machines and sensor-based robots

The term "robot" has no exact definition even within robotics industry. However, the most widely accepted definition is the one adopted by the Robotics Institute of America:

"A robot is a programmable multifunctional manipulator designed to move materials, parts, or specialized devices through various programmable motions for the performance of a variety tasks."

Robot is one type of computerized numerical controlled(CNC) machines. These machines can be programmed to perform different functions. Robot can be considered as the most advanced type of CNC. The latest trend of CNC is towards the sensor-based robots.

A study submitted to the National Research Council in 1982 indicated that robots vary considerably in cost. Middle-range technology robots that can have simultaneous moves sell for \$20,000 to \$30,000. In the top price range is the high technology robots which can be programmed to operate anywhere within its designated area of movement. They have the capability to store and execute more than one program and are priced from \$25,000 to \$150,000. Normally, manufacturing plants implement robots in the whole plant or parts of the plant though the implementation process may take several phases. This means that many of these robots are purchased

in this process; thus, the total cost of a modernization project may require many times of the cost of one robot.

2.2. Computer-Aided Design and Manufacturing (CAD/CAM)

CAD/CAM comprises a general purpose digital computer, a CAD/CAM work-station, plus CAD/CAM software. The creative link between the designer and the computer is the electronic pen. By dictating commands on an electronic pad, the designers' ideas become a precise, geometric, 3-D reality on the computer graphics screen.

The capabilities of the computer have evolved from initial emphasis on computation ability to the inclusion of logical ability, memory and the graphic display and output. The advent of graphic displays has enabled the automation of the draftman's and engineer's tasks. Due to this enlargement in scope, the name of the activity has been appropriately changed from engineering computation to Computer-Aided Design (CAD).

Using CAD, engineers can develop alternative designs on a computer terminal to determine the best way to meet product specifications. The computer can store formulas and can integrate separate components into a composite design. This can again be modified. Engineers can then use the resulting mathematical diagram to produce drawings, to generate data on costs at different volume levels, or to provide instructions for manufacturing, testing, scheduling, inventory control, and shipping.

As CNC machines are used in the shop floor, they can be integrated with CAD system and the engineering instructions generated by CAD can be directly transmitted to the CNC machines to produce the product according to the instructions. The whole process from design to manufacturing is thus called CAD/CAM.

A CAD/CAM turnkey system may cost as low as \$100,000. Thus, small and medium-sized machine shops can afford a CAD or CAD/CAM system. However, the more

sophisticated system may cost well over \$600,000. A survey by the Canadian Machinery and Metalworking Association indicated that most of the turnkey systems sold in Canada are in the range of \$300,000 to \$600,000.

Goldhar and Jelinek(1983) has given a very good comparison of traditional technology and CAD/CAM technology. Their comparison is shown in Table 2.1. Economies of scope exist where the same equipment can produce multiple products more cheaply in combination than separately. This is achieved in the CAD/CAM environment as compared to economies of scale in the traditional environment.

TABLE 2.1: COMPARISON OF CAD/CAM AND TRADITIONAL ENVIRONMENT

<u>TRADITIONAL</u>	<u>CAD/CAM</u>
1. Economy of scale	Economy of Scope
2. Experience curve	Truncated product life cycle
3. Task specialization	Multimission companies
4. Work as a social activity	Unmanned systems
5. Separable variable costs	Joint Costs
6. Standardization	Variety
7. Expansive flexibility and variety	Profitable flexibility and variety

Source: Goldhar and Jelinek(1983)

2.3 Flexible Manufacturing Systems(FMS)

There has been no universally accepted definition for FMS. However, the following two definitions seems to be representative:

"FMS are engineered, computer controlled, manufacturing processes that can adopt automatically to random changes in product design configurations, models, or styles. The system will always strive to optimize production output and work in process inventory." (Phillips, 1983) and

"FMS are integrated systems of computers, CNC machine tools, inspection units, and some automated material handling devices such as shuttle pallets, carts(robot carriers) and industrial robots. The raw parts are manually loaded and unloaded at a central load/unload station. Real-time computer control system moves the carts with the fixtures and the parts to the required workstation for processing. Upon completion, the part is transferred by a cart to its next work station, to the load/unload station, or to the buffer area (pallet stocker) where it queues temporarily."(Arbel and Seidmann,1984)

FMS has been part of the manufacturing setting; however, progress was relatively slow. The automatic transfer lines used by the automotive industry are probably the birth of FMS.

In today's competitive environment, product life cycle has been shortened and manufacturers cannot afford to set up fixed production lines. In order to provide a variety of products or the same product with a variety of features, manufacturers are forced to adopt flexible manufacturing. This is why FMS is becoming more and more attractive for some firms. With the rapid development of microprocessor technology, FMS is expected to become relatively wide-spread in Japan and U.S. Also, other countries like Britain, West Germany, France, and Canada have high potential of implementing FMS. In fact, a number of FMS have already been in operation in these countries.

2.4. Common characteristics of AMTs

In the above three sections, Robots, CAD/CAM, and FMS have been discussed separately. These three technologies have some very similar characteristics that set them apart from the traditional manufacturing technologies. Also because of these unique characteristics, practitioners and researchers have been arguing about the suitability of the use of capital budgeting techniques in justifying these technologies. In order to have a better understanding of this controversy, the unique characteristics of these AMTs are summarized as follows:

(1) Economies of Scale Versus Economies of Scope

Four current trends in the manufacturing industries have to be recognized. First of all, there is the increasing internationalization of competition, markets, and production technology. The second trend is "demassification." This is the process of shifting from mass production of standard products to a variety of lines of

custom-made products. Third, the life cycle of the product has been shortened to a few months. Finally, the product complexity is increasing. The success of Canadian manufacturers depends on whether they can take advantage of these trends.

Traditional equipment usually directs the plant towards economies of scale. In particular, greater production volumes display lower unit costs than do lesser volumes. Greater volumes allow for the use of expensive special-purpose equipment, which in turn is justified only by large-scale operations. By contrast, the AMTs drive the plant towards economies of scope where the same equipment can produce multiple products more cheaply in combination than separately. AMTs employ new computer technology which makes the plant possible of producing small batch efficiently.

FIGURE 2:1: PRODUCT-PROCESS MATRIX

Figure 2.1 depicts the direction of the traditional technology and AMTs. It can be seen that traditional technologies are toward economies of scale whereas AMTs are toward economies of scope which is the current trend.

(2) Flexibility

As mentioned earlier, most of the AMTs have reduced the lead time and thus can manufacture a product faster than the traditional production methods. Moreover, through the application of computer technology, a product design can be changed rapidly to respond to the changes in market needs. When demand changes, machines can be setup easily to produce different kinds of products in desired volume. This adjustment can be performed continually. In fact, AMTs are designed to have this capability.

As a result of production and scheduling flexibility, product can enter the market in a shorter time and in a flexible volume. This quick response to the market generates tremendous intangible benefits. First of all, forecasting of short term product demand becomes easier and more accurate since managers do not have to predict many weeks ahead of time to allow time for design and production. Second, being an early entrant to the new product market, it is easier to capture market share and create brand loyalty.

In addition to quicker responses to market needs, the diversifiable risk of the firm is lower using AMTs. It is because the ability to rapidly shift between products reduces the correlation of the plant's cash flows with general economic conditions. Consequently, the risk will be reduced.

Moreover, as Kulatilaka and Marks(1985) have shown, even in a world of certainty (riskless world), flexibility can confer a strategic advantage in a bargaining environment. This is important because a significant number of input and output prices are determined through negotiations rather than through the open market.

In short, flexibility offered by AMTs has generated better response to changing market situation, lower risk and greater bargaining power.

(3) Quality

The quality of output are far more uniform using AMTs than traditional technologies since human involvement in the process is reduced. For example, the use of CAD/CAM helps to eliminate human error by ensuring that all calculations are correct based on supplied data. This results in higher and consistent quality. The reduction in sales returns, breakdowns, warranty repairs, and recalls cannot be accurately predicted or measured *ex ante*. Moreover, the higher quality and greater reliability of the product improves the firm's image in the market which is even harder to quantify.

(4) Employee Motivation and Potential Learning Curve Effect

AMTs often give higher responsibility and authority to the workers. In the best scenario, this generates better employee motivation and suggestions to improve the system. The latter is more obvious in the Japanese factories where AMTs provide challenges to the employees to lower retooling time, reduce set-up time, and achieve higher machine utilization rate. These generate a spiral which continually improve the system.

(5) Increase Variety and New Product Option

Most of the traditional technologies emphasize in mass production to achieve low cost. As a result, the manufacturing process is relatively inflexible. New products or varieties of the same product are produced only if the potential demand is high. As a result, competitors easily surround the single product firm by producing similar products with a variety of features that the single product firm does not produce.

Moreover, under the traditional production technologies, managers are

reluctant to produce new products since it, at least in its infancy, drives down the profit figure because new product cannot be produced as efficiently as the mature products. Also, the new products may "interfere" in the production of existing products (e.g. extra set-up time).

On the other hand, the AMTs are relatively flexible and the new product can be manufactured simply by reprogramming the CNC machines or a new design can be generated very quickly. Consequently, many new product options are opened up and varieties of the same product can be produced cheaply. Economies of scope can then be achieved.

(6) Implications of Predictable Manufacturing Schedule

With AMTs, products are manufactured in time and in desirable quantity. This translates to lesser stockout. Moreover, management can pay less attention on production and delivery scheduling. As a result, more time can be devoted for strategical planning.

Because of these six unique characteristics of AMTs, firms using them are more competitive and have a higher chance of long term survival. Conversely, firms which do not employ AMTs are less flexible, and its lower level of adaptability to unforeseen changes in demand condition threatens to drive these firms into bankruptcy. Thus, to ensure future survival, it is necessary to consider whether or not the Canadian manufacturers are striving for AMTs.

3. LITERATURE REVIEW

An examination of the literature dealing with the justification of AMTs that has appeared over recent years reveals four patterns. First, an imbalance between the survey articles and the analytical articles can be found. Second, there is a research direction towards the development of models to solve the problem in AMT justification. Third, there have been a number of different viewpoints with regard to the underlying causes of the slow adoption problem. Fourth, the focus is on the financial justification stage. Other stages prior to the financial justification stage of the decision making process are neglected.

Most of the literature is on the analytical side. It assumes that Canada is lagging behind in AMT investment. There are only two studies which can be considered as survey of applications of AMTs in Canada. These are discussed in Section 3.1.

In terms of analytical articles, a clear research direction can be seen. Initially, the research work is directed towards the uncovering of problems in evaluating AMTs. Although different researchers have different views about the problem, there is a strong focus on the appropriateness of capital budgeting techniques used in evaluating AMTs. After some of the perceived causes of slow AMT adoption are identified, considerable efforts have been spent on the quantification of benefits of AMTs that are not taken into consideration by the traditional capital budgeting methods. Finally, some models are built to incorporate these missing factors into the decision making process. Brief discussion of these models are found in Section 3.2.

As mentioned above, different researchers have different views about the problem of slow AMT adoption. These views can be summarized under six categories and are discussed in Section 3.3. Since no studies on AMT decision making process can be identified, Section 3.4 discusses two organizational behaviour studies on decision

making process in general.

3.1 Results of survey studies

A study by Robertson(1982) can be considered as the earliest empirical work in this area. In his survey, he found that Canada is lagging behind in the adoption of robots. He further noted that there is a low level of awareness concerning robotics. His findings about the concentration of robots in the automotive industry and large foreign subsidiaries are in fact the current Canadian picture.

A recent survey of AMT adoption in Canada is conducted by Craig and Noori(1986a,b). In their survey of 515 firms with sales between \$1 million and \$5 million, Craig and Noori noted that many small firms are aware of the importance of AMTs. However, these firms do not have sufficient knowledge and expertise in the kind of technology they need or should acquire. Also, Craig and Noori found that government sponsored technological centres have not been able to penetrate the smaller manufacturers. In addition, both the large and small firms consider availability of capital the major barrier to automation.

These two studies have given a rough picture of AMT adoption in Canada. However, none of these studies specifically describe the patterns and trends of AMT application in detail.

3.2 Analytical research efforts

An examination of the literature dealing with the economic justification of AMTs that have appeared over recent years reveals a three-stage research efforts. These stages are: problem discovery, missing factor identification, and measurement.

(1) Problem Discovery Stage

In the problem discovery stage, researchers noticed that although AMTs offer improved productivity and flexibility, they are difficult to justify using traditional

project evaluation techniques, especially the capital budgeting techniques.

Project evaluation and selection is the process of evaluating individual project or a group of projects, and then choosing to implement some set of them so that the objectives of the parent organization will be achieved. There are two basic types of project selection models, numeric and non-numeric. Both are widely used. Many organizations use both at the same time, or they use models that are combinations of the two. Non-numeric models do not use numbers as inputs whereas numeric models do. Since the nonnumeric models are often simple, unscientific and are based on subjective judgment, they are not discussed here. The numeric models can be divided into subjective numeric models and objective numeric models.

The subjective numeric models use multiple criteria to evaluate a project. Usually, a scoring method is used to measure the multiple criteria. The main types include unweighted 0-1 factor model, unweighted factor scoring model, and weighted factor scoring model. The objective numeric models mainly include those that use profit or profitability as the sole measure of acceptability. They can be called capital budgeting techniques. Five common techniques are the payback period, return on investment, net present value, internal rate of return, and profitability index. A detail discussion of the characteristics and the problems of using these numeric models in evaluating AMTs are presented in Appendix 2.

Researchers, such as Gold(1982), Kaplan(1983), Kulatilaka(1984), and Meredith and Mantel(1985), have criticized the project evaluation process used by many of the North American companies. They believe that the excessive risk adjustment, failure to take into consideration of future growth opportunities, and the inability to properly account for difficult-to-quantify factors are the major barriers for adopting the AMTs. Their views of the problem of the evaluation process are

discussed in detail in the following section. Before discussing their views, it is essential to understand the project evaluation process itself.

For example, Gold(1982) pointed out that most capital budgeting evaluation criteria have evolved from efforts to deal with a continuing flow of incremental improvements. However, some advanced automations such as Computer-Aided Manufacturing represent much more than incremental improvements. He stressed that CAM's contributions are likely to keep increasing for extended periods beyond initial installation due to better understanding of the system by technical specialists and rapidly advancing improvements in computer technology.

Although Herroelen and Lambrecht(1984) believed that traditional capital budgeting techniques will still be the basic tool to evaluate investment proposal, they voiced concern over the narrow view of these traditional techniques and pointed out that return on investment drops sharply as the ratio of fixed assets over sales increases. AMTs usually represent substitution of labour with machines, acquisition of new production equipment, and other means of transforming a plant from job shop to mass production usually increases this ratio. As a result, investment in AMTs when evaluated using ROI always gives an unfavourable appraisal. This view is also shared by Gale(1980). Herroelen and Lambrecht also commented that the generation of cash flow estimates always ignore the consequences in terms of the competitive position of the firm with respect to the other competitors if the project is not adopted.

All these criticisms of the traditional method have driven the research efforts for finding of "missing factors," i.e. what are the contributions of AMTs that are not measured by the traditional methods?

(2) Missing Factor Identification Stage

In this stage, researchers try to discover the important factors that have been

ignored. Some believe that when these factors are incorporated in investment consideration, AMTs will be evaluated fairly.

One of the pioneers who try to identify these missing factors is Kaplan(1983). He criticized the traditional Discounted Cash Flow (DCF) methods for evaluating new investment proposals. He argued that the narrow interpretation of this procedure may inhibit desirable investment projects. He believed that the danger was from relying solely on the easily quantified savings in input factors -- such as labour, energy, and materials -- from new capital investments and not considering gains from improved manufacturing performance that are more subjective and difficult to quantify. Such difficult-to-quantify factors include product quality, manufacturing flexibility, reduced inventory levels, and the capacity for increased product innovations. His view is echoed by Goldhar and Jelinek(1983).

Some articles in engineering journals have detailed the technical costs and benefits of the AMTs. Klahorst(1983) described 14 production costs affected by AMTs in an effort to provide a better estimate of the benefits of AMTs. In addition to the strategic and technical benefits, Kulatilaka(1984a) discussed some factors such as retraining labour and/or hiring labour with new skills.

As these new factors are identified, the next stage of research deals with the measurement of these factors. Since the AMTs are still in their embryonic stage, these factors, both quantitative and qualitative, are not easy to measure and require a lot of subjective judgment.

(3) Measurement Stage

Due to the problem involved in measuring these factors, little work has been done in incorporating these factors in the capital budgeting framework. A few recent articles, however, have shed some light into the future research direction.

Kulatilaka(1985a) and Nelson(1984) have constructed evaluation models which have taken some of those missing factors into consideration. Also, Hutchinson and Holland(1982) have begun a promising attempt to quantify the value of "flexibility." This is further studied by Kulatilaka(1985b).

Kulatilaka(1985a) demonstrated that flexibility, stable product quality, and some predictable marketing costs have led to less risky cash flows under AMTs. Thus, by lowering the rate used in discounting cash flows, these factors are indirectly incorporated into the capital budgeting decision. Consequently, traditional DCF methods can be used to evaluate the AMTs. However, his model does not consider such factors as strategic importance of the investment decision, competitiveness of the firm, and the other hard-to-quantify factors. The model's inadequacies are mainly attributed to the quantitative nature which is restricted to numerical data.

On the other hand, Nelson's scoring model required the conversion of some data from interval scale to ordinal scale or zero-one indicators. The model incorporates the score of five additive terms: technology assessment, equipment evaluation, workload elasticity of capacity score, cost/budget ratio, and net present value score. He argued that his scoring model has a distinct advantage when the value of some variables of AMTs are still unknown. Thus, the model fills a distinct planning need, by processing criteria for which economic data are not available. However, the model is designed to evaluate several projects and it is not easily applicable for the evaluation of a single project. It is because the score of each factor is weighted by the total scores of the same factor among several projects. Moreover, the model is not flexible since equal weight is assigned to each factor. Finally, the model only takes part of the missing factors into consideration; some of the important factors are still missed. There seems to be a need for flexible and comprehensive models which will measure, taking the quantitative and

qualitative nature of the factors into consideration, all the important factors so as to aid financial managers to fairly evaluate the desirability of acquiring the AMTs.

Kaplan(1986) suggested that managers first compute the NPV by ignoring the qualitative factors. If the quantitative factors are not enough to justify the investment (i.e. a negative NPV is found), it will become necessary to estimate how much the annual cash flow must increase before the investment does have a positive NPV. Management then exercise their judgment on whether the qualitative factors are worth the amount needed to convert the negative NPV to zero.

All of these models suggested by the literature have not been tested empirically and, therefore, the applicability of these models have not been proven.

3.3. Views of the cause of the problem of slow AMT Adoption

It is generally accepted that problems exist when traditional capital budgeting tools are used to measure the desirability of AMTs. However, whether the problem is due to the techniques themselves or the misapplication of the techniques is still controversial. Some strongly believe in the classical view that the traditional methods work but they are misused. Another view is the engineering view which believes that if the production costs and savings of AMTs are measured carefully, the problem will disappear. This is closer to the classical view. On the other hand, another group (strategic view) believe that AMTs change both the internal and external environment of the firm. Investment in AMTs is a strategic one and the traditional capital budgeting methods cannot portray the long term effects of the AMTs. Finally, some researchers, as represented by Kaplan(1983), looked at the problem from a very different angle. They observed that traditional cost accounting procedures which pro rate overhead using direct labour costs are biased since labour cost in AMTs are not as significant as the traditional manufacturing techniques. This accounting view believes that the

estimation of cost savings is often biased against the adoption of AMTs.

The classical view, engineering view, strategic view, and accounting view are discussed in turn. Also, since they are not mutually exclusive, a mixed view is discussed.

(1) Classical View

According to Hodder and Riggs(1985), the managers who applied the capital budgeting techniques, not the techniques themselves, are the problem. The discounting procedures are not inherently biased if management sets realistic hurdle rates and examines carefully its own assumptions. Hodder and Riggs believe that managers and decision makers should carefully consider the effect of inflation, the different level of uncertainty in different phases of a project, and management's own ability to mitigate risk when the discounted cash flow analysis of risky projects are employed. Most importantly, they see that managers use excessive risk adjustments, particularly when risk declines in later phases of a project; therefore, they believe that risk adjustment should be divided into several phases. As the project becomes more certain, the risk adjustment should be lowered.

Their suggestions undoubtedly are useful for managers to evaluate risky projects which have no significant impact on the firm's internal and external environment and where past data is available to evaluate riskiness of the cash flow. However, for the AMTs, their suggestions only can solve part of the problem. Not only are AMTs risky projects, they also change the organization significantly. Moreover, the technology is so new that no reliable data are available to present an accurate estimation of the risk and potential "learning curve" effect. Risk-averse managers are reluctant to use an optimistic discount rate; rather, a conservative rate is more likely to be used. In addition, they do not present convincing arguments with respect to

how the traditional techniques can incorporate the impact of changing the organization's competitiveness and flexibility.

(2) Engineering View

This view is somewhat narrower but consistent with the classical view. The engineering view focuses on the measurable and production-related benefits of the AMTs. Klahorst(1983) and Stokes(1982) both tried to identify the advantage of AMTs on the factory floor. They believe that the strength of justifying AMTs rests in the proper evaluation of the operating differences of the AMTs and existing technology; thus, by investigating many cost savings of AMTs and generating calculations of these savings, there is a higher chance for financial managers to accept AMTs.

The motivation of this group of researchers is to introduce AMTs into the organization. Their motivation is not to find a proper measure of the desirability of AMTs; rather, they intuitively believe that AMTs are desirable and then find ways to justify their desirability. Although the motivation is to revert the bias against AMTs, it provides some valuable contributions. First of all, their efforts in detailing the cost savings of AMTs in the long run will provide better estimates of the measurable benefits of AMTs. With these better estimates in the near future, managers will be more confident with the AMTs and may lower the hurdle rate as some perceived risk is eliminated.

(3) Strategic View

During the last five years, many articles have discussed the strategic importance of AMTs. As early as 1980, Gale(1980) suggested that rather than evaluating investment in new equipment as a simple choice between increased capital costs and reduced labour costs, management needs to consider the long term consequences of mechanization. Increased investment always affects the competitive

climate; in the short run, it almost invariably reduces return on investment but the long run outcome depends on how a business is structured within its own economic environment.

In addition to the above concerns, Gold(1982) suggests that evaluation of AMTs should be done using a longer time horizon and a consideration of the long term implication of not investing in AMTs.

Goldhar and Jelinek(1983) think that the strategic advantages directly challenge most current assumptions about manufacturing that stem from the notion of economies of scale -- in particular, the notion that greater production volumes display lower unit costs than do lesser volumes. Greater volumes allow for the use of expensive special-purpose equipment, which in turn is justified only by large-scale operations. By contrast, the new technical capabilities rest on economies of scope -- that is, efficiencies wrought by variety, not volume. Herroelen and Lambrecht(1984) presented the same argument by using product-process matrix. They conceived that AMTs can be used to break out of the vicious circle of lower net profit margins on sale and higher investment in automation by moving as fast as possible to a mass production with diverse, rather than standard, products in the traditional automation process product.

Schmenner(1983) also presents convincing evidence of the necessity to use AMTs for future survival. He noted that failure to keep up with new technological opportunities all contribute to the decline of facilities that eventually fail.

As indicated in most of the above research, AMTs are needed for long term strategic success and survival. However, current management is rewarded for its current performance. It may be to their interest to maximize short term profit. Mere strategic importance is not enough to motivate financial managers to accept projects in

AMTs

(4) Cost accounting View

Kaplan(1983) has taken a view that the traditional capital budgeting approach is too narrow. He proposed that accounting researchers should attempt to develop non-financial measures of manufacturing performance, such as productivity, quality, and inventory costs. Measures of product leadership, manufacturing flexibility, and delivery performance could be developed for firms bringing new products to the market place. He stressed that cost accounting should develop indicators that are more consistent with long term competitiveness and profitability instead of the current practice which focuses on aggregate, short-term financial measures.

In the traditional cost accounting procedures, overhead costs are allocated as a percentage of direct labour cost. This procedure has also received many criticisms. As Stokes(1982) pointed out, this procedure is impossible to apply to AMTs since in AMTs the direct labour cost as a percentage of total cost is significantly lower than traditional technologies and does not represent a good base for allocation of overhead costs.

(5) Mixed Views

Since the four views presented above are not all mutually exclusive, many researchers process more than one view. For example, Suresh and Meredith (1984), and Kulatilaka(1985a) express both the classical and engineering view. It is expected that reconciliation among these views will become more popular as researchers learn more about the strengths and weaknesses of each view and know more about the AMTs.

3.4 Studies on decision making process

As mentioned, no studies on the entire AMT decision making process can be identified. Most of the AMT literature only concentrates on the financial justification

stage of AMTs and neglects other stages that are important, but less obvious, in the decision to invest in AMTs.

An examination of decision making studies in the organizational behaviour literature reveals two studies in the decision making area. Studies by Mintzberg, Raisinghani, and Theoret(1976) and Nutts(1984) have made major contributions to the study of decision making process in organizations. Mintzberg, Raisinghani, and Theoret decomposed the decision making process into several stages which they called them recognition, diagnosis, development, and selection. Using a somewhat different framework, Nutt found that decision making process can be divided into five stages: formulation, conceptualization, detailing, evaluation, and implementation.

Using knowledge gained from these two studies, Section 8 attempts to decompose and analysis the AMT decision making process.

4. RESEARCH QUESTIONS

The development of AMT literature and the different views held by researchers are based on certain assumptions which may or may not be appropriate. In particular, researchers make a number of assumptions related to the perceived pitfalls of AMT investment evaluation procedures used by the decision makers in the industry. The researchers usually assume that managers: 1) put too much emphasis on labour cost savings; 2) understate the importance of flexibility of AMTs; 3) assume business will continue as usual; and 4) suffer from the inadequacy of capital budgeting techniques especially the DCF methods in their evaluation of AMTs. The researchers believe that these are the major barriers to AMT investment.

These assumptions, either explicit or implicit, have not received enough investigation as to whether or not they are appropriate. And yet they are the building blocks for some of the evaluation models and views of the problems. Examination of these assumptions will help to substantiate and/or dispute these models and views; and thus, to advance our understanding of the AMT investment decision making process.

For those assumptions that are found to be appropriate, more confidence can be placed in those models that are developed using them, and more convincing are those views that incorporated them. For those assumptions that are found to be inappropriate or inconclusive, the validity of the models and the logic of the views should be seriously questioned. This, then, provides a good basis for future research.

Due to the importance of these research assumptions, this section outlines four research questions that are derived from the research assumptions used, implicitly or explicitly, in the current literature. The procedures to examine these research questions are presented in the next section.

4.1 The treatment of direct labour costs

In the past, much effort has been spent on attempting to determine the appropriate costs that should be involved in considering AMT investment. Although practical measurement problem still exists, most of these costs are now tractable.

However, researchers do have different evidence of treatment of these costs. Some reported that they frequently encounter firms that restrict cost justification to labour savings alone, despite the diminishing role that labour is generally playing as part of the manufacturing costs. Hill(1986) stressed that "this is an obvious problem [restrict cost justification to labour savings alone] that can and should be corrected immediately."

Hill's criticism implied that the decision making process is biased against AMT investment since AMTs provide much more than direct labour savings. However, his concern is not supported by empirical data. He did not specify the number and the type of companies he has investigated.

In the Canadian context, a survey of 1500 small manufacturers conducted by Craig and Noori(1986a) found that the increasing cost of labour is a most important reason for automation. Whether this is true for the larger manufacturer is still unknown. It is likely that firms do not restrict AMT investment to labour savings alone. Authors such as Klahorst(1983) have listed a wide range of costs that are involved in the AMT justification process. The costs are direct labour, machine setup, tooling, material handling, part inspection, equipment maintenance, shop supervision, production control, manufacturing engineering, plant facilities, inventory, fixturing, prototype and new part, and rework and scrap.

A report published by Westinghouse Canada⁵ has also given some insights into this problem. The report states, "direct labour has diminished to less than 5% of

product costs on some of the company's products. Therefore, a superficially applied ROI yardstick can obscure management's vision of the very critical elements of overhead and cycle time. In critical business situations (survival), this oversight will quite often lead to a completely wrong decision."

Thus the controversy is not whether the costs are measurable; it is whether the labour savings are a most important item in justifying AMT investment. Most of the researchers believe that managers have put too much emphasis on labour saving function of AMTs. However, other costs listed above are not new and are measurable. Moreover, the most important contribution of AMT is not cost savings but flexibility. Therefore, it will not be surprising if one finds that labour saving is not a most important item in justifying AMTs.

In short, the research question is:

Are labour cost savings a most important consideration in justifying AMT investment?

4.2 Flexibility assumption

AMT investment may be motivated by the positive incremental savings, the need for strategic changes, or both. AMTs do provide the opportunity for strategic changes; however, it is unclear whether or not these strategic changes are the intention of adopting AMTs or just the by-product of adopting them.

For a proper evaluation, the flexibility offered by AMTs should be a major strategic consideration because of the need to stay with the four current trends in the manufacturing industries that have been discussed in Section 2.4.

Therefore, it is important to find out whether firms invested in AMTs are trying to take advantage of these four current trends by improving production flexibility. Thus, the following research question is appropriate:

Are those firms that invested in AMTs trying to increase their production flexibility so as to produce goods at a cheaper cost and faster rate?

4.3 Status quo assumption

With the growing internationalization of markets, Canadian manufacturers must not assume that "business will continue as usual." Thus, when the capital budgeting technique is used, it must not be used to compare a "do nothing" approach with the AMT investment approach.

Traditional capital budgeting techniques measure the incremental benefits (benefits generated from the investment as compared to results extrapolated from current business) generated by a project. If that incremental benefit is positive, the project will be undertaken. However, in the intensive competitive environment, decision makers should assume that no investment will lead to a decline in business. This assumption is more appropriate than to just measure the incremental benefits from current business extrapolates.

Although, theoretically, the assumption that no investment leads to decline in business is more appropriate than the status quo assumption, it is unclear which assumption the Canadian manufacturers are using.

Some recent articles such as Hill(1986) have suggested that the status quo assumption is a major barrier to AMT installation in Canada. This criticism is not supported by empirical data. Therefore, the answer to the research question below can validate this criticism:

Is the measurement of AMT benefits done by comparing the current business extrapolates with the estimated results after installing AMT?

4.4 The adequacy of capital budgeting techniques

Companies use different ways to justify their investment decisions. These

include the capital budgeting techniques (i.e. NPV, ROI, payback period etc), strategic justification, and scoring methods. Anyone of these, or a combination of these, may be used in the justification process.

Among these methods, according to the literature, capital budgeting techniques are most commonly used. The use of these techniques is not without problems. For instance, a survey by the Financial Management Association⁶ revealed that a majority of firms encountered problems when using these techniques. The major problems are strategic considerations and risk analysis.

These findings coincide with the growing concern of the ability of capital budgeting techniques to justify the important intangible benefits of AMTs, most of which are strategical. This is because AMTs offer the kind of flexibility and strategical advantages that are not available in the traditional technologies.

The second problem of capital budgeting techniques is the difficulty in performing the risk analysis. The risk of AMTs declines in later phases. Much of the risk of AMTs incurs in the implementation stage. It usually takes one to two years to have a robot or CAD/CAM fully in operation (longer for FMS). After that, the risk will actually be smaller than conventional technology since the quality of the goods becomes more consistent, the production schedules more predictable, and the maintenance costs more stable. Therefore, different discount rates should be used to capture different levels of risk in different phases of the AMT life cycle. Thus, it is important to find out whether current practices in the industry have taken the changing risk characteristic of AMTs into consideration.

Researchers such as Hodder and Riggs(1985) have commented that a single risk adjusted rate is used in most situations. They explained how a single rate implies an important and somewhat special assumption about the risks associated with future

cash flow estimates: such risks increase geometrically with chronological distance from the present.

This assumption is in direct conflict with the risk characteristic of AMTs. Therefore, if a single rate is used, the AMT evaluation will not be treated fairly. However, a number of reasons could be advanced to defend the choice of a single rate. For instance, it is simpler to use a single rate than multiple rates, especially when the decision making process involves different functional areas. Decision makers have to make sure that the evaluation techniques are acceptable both for the financial and technical staff in the decision making process. Moreover, the ability to predict accurately decreases with time; thus, cash flows that are far away are riskier than those that are closer to the present. This implies that a single rate that portrays risk increases geometrically with chronological distance from the present makes sense.

Theoretically, multiple rates with decreasing rates for future cash flows should be used in evaluating AMTs. However, practically, a single rate is more attractive. In practice, one should expect that the simpler one, i.e. the single rate, prevails.

To better understand how capital budgeting techniques are used despite the intangible benefits and risk analysis problems, the following research question needs to be answered:

What is the role of capital budgeting techniques in the AMT investment decision and what other methods, if any, are used to supplement the inadequacy of capital budgeting techniques?

5. METHODOLOGY

To answer the four research questions discussed in Section 5, this study is divided into the preliminary and the main stages. In the preliminary stage, an empirical survey of the characteristics of the firms that have AMT investment is conducted. This is followed by the main stage which involves holding interviews with a selected number of firms.

The preliminary stage is important in a number of ways. First of all, it provides a comprehensive picture of the AMT applications in Canada. Some trends and patterns with regard to the adoption of AMTs by industrial sector, firm size, location and other factors have been uncovered. Secondly, the survey results are used in developing the sample, preparation of interviews and to ensure that the samples that are selected are not biased in terms of size and industry. Thirdly, the survey results are helpful in the analysis of interview results. A detailed description of the preliminary stage is presented in Section 5.1.

With the information provided by the preliminary stage, interviews were conducted and results analyzed in order to provide answers to the above research questions. Through the answers to the research questions, some research assumptions can be supported and some challenged. The details of how the interviews are conducted and how the results are analyzed are presented in Sections 5.2 and 5.3 respectively.

5.1 Preliminary stage –trends and patterns of AMT adoption In Canada

As mentioned before, there is no comprehensive study of the application of AMTs in Canada in recent years. In the early 80s, two separate studies of CAD/CAM and Robots⁷ gave detailed description of the applications of these technologies in Canada and their outlook. It has been over five years since these two studies were published and the advancement in technology, especially computer technology, has drastically changed the

sophistication, application and cost of the AMTs. As a result, an up-to-date and comprehensive study on AMT adoption in Canada is needed. This study provides some basic information on the AMT adoption in Canada. It is hoped that, before an up-to-date and comprehensive study on AMT adoption is done, this basic information can give a general picture of AMT adoption in Canada.

Through analysis of the types of firms that are using AMTs, current patterns of their applications can be seen. When the patterns are compared with historical information, trends can be traced and projections for the future can be made. Since only nine firms in Canada have FMS, cross comparison among the characteristics of these firms shows some patterns and/or trends, if any. The large number of firms using robots and CAD/CAM (105 for robots; 238 for CAD/CAM) warrant the classification of these firms into categories. The bases of the classification will be as follows: 1) year of adoption; 2) sector of the economy; 3) type of manufacturing; 4) size of firm; 5) type of application; and 6) ownership.

The Canadian Machinery and Metalworking "86 Hi-tech Census," May, 1986 will be used as the primary source of data. This census provides names of the corporation that have adopted CAD/CAM and robots. Other information include the model of CAD/CAM and robot, type of applications and the year of adoption. This information, however, is not enough to carry out the aforementioned goals. A list of sources that are used to supplement the "86 Hi-tech Census" are listed in Appendix 3.

Information for the large firms are readily available in the Financial Post Cards and their annual reports. However, the information for the medium and small firms is harder to find and require cross-reference to several sources listed in Appendix 3.

5.2. Main stage – Interview methodology

The purpose of the interviews is to provide insights into the decision process and answers to the four research questions. The sampling process to identify sample firms for interview is as follows:

(1) Define Population

The elements of the population are the executives involved in the AMT investment decision. The sampling units are firms with AMT installations in Canada in the last 5 years.

(2) Select Sampling Frame

The sampling frame contains a list of firms that meet the following three requirements:

i) for firms have CAD/CAM or robot installations, they have to be listed in the "86 Hi-tech Census," Canadian Machinery and Metalworking, May, 1986. This listing is deemed to be the best available source that represents the population of firms that have installed CAD/CAM and robots. Also, they have to satisfy the following two conditions. Any firms with FMS installations are included if the following two conditions are met.

ii) they are located in the vicinities of Ottawa, Kingston, Toronto, and Waterloo-Kitchener areas. This is to ensure that sample firms are in a reasonable distance in order to minimize travelling expenses; and

iii) they are not research institutes, universities and colleges, and other educational and training centres. Exclusion of these non-manufacturing organizations are essential in order to focus our attention on the manufacturing firms.

(3) Choose Sampling Design

The sampling design is a random sampling type complemented by the use of

nonprobability judgment with quota type design. Specific procedures are described in (5) of this section. The sample selection tries to achieve a balance among the three technologies (CAD/CAM, Robots, and FMS) after taken into consideration of the number of firms using each technology in order to capture the possible differences in these three technologies. Thus, although the ratio of firms that have CAD/CAM, Robots, and FMS is 238:106:9, a minimum of 2 firms in FMS are selected.

(4) Determine Sample Size

After taking into consideration of the size of the sampling frame, scope of this study, and financial and time constraints, a sample of 22 firms are selected. According to the criteria specified above, 10 firms from CAD/CAM, 10 from robots and 2 from FMS are used. Although all of these firms are from Ontario, the study provides an important snapshot of the larger Canadian situation since Ontario has more manufacturing firms and workers and produces more manufacturing goods than any other provinces.⁸

(5) Design Sampling Plan

The sample are selected and the data are collected in the following manner:

i) for FMS sample: a random sample of four firms that use FMS from the sampling frame; and

for CAD/CAM and robot sample: a random sample of twenty firms in each technology.

A total of 44 firms with 4, 20 and 20 that uses FMS, CAD/CAM and robot respectively are selected.

ii) Send letters and brief descriptions of the type of information wanted to the top executives of the 44 firms to request for interviews. The letter and the attachment are shown in Appendix 4.

iii) Call for interview appointment. For FMS, two firms are interviewed whereas for CAD/CAM and robots, 10 firms of each are interviewed. The extra letters are used to allow refusal for interviews or other reasons that may prohibit the interview arrangements.

iv) Conduct interviews;

vi) Conduct follow-up interviews, if necessary.

Following the above sampling process, executives from 22 firms are interviewed. The interviews are conducted using a semi-structured style. The interviewees are asked a number of questions. The information required from the interviewees is listed in Appendix 5. Both the interviewer and interviewee also have the flexibility of exploring other issues or discussing certain questions in depth whenever necessary. This not only allows the interviewer to collect answers for the prespecified questions but also stimulates the interviewees to express any issues that they feel are of importance to the AMT investment decision.

5.3 Analysis of interview results

After the survey and interviews are done, analysis of the data is carried out so as to provide suggestions to the validity of the four research assumptions used by the researchers. Both quantitative and qualitative analysis are used to accomplish this purpose.

Quantitative analysis include the use of different statistical tests of the hypotheses generated from the research questions. They are discussed in section 5.3.1. These statistical tests enable the researcher to test a specific set of hypotheses derived from the research questions. However, the tests are not able to provide the rationale behind the test results nor can they give a more indepth and broader answers to the research questions. Thus, section 5.3.2 outlines the qualitative procedures that are

used to supplement the above insufficiency.

5.3.1 Quantitative Analysis

The analysis are carried out in the following manner. Specific data are collected from the interview to address each research question. The data are tabulated and individual hypotheses bearing upon each research question are statistically tested. Then, using the secondary data and the qualitative results from the interview, some explanations for the findings are provided.

(1) The Treatment of Direct Labour Costs

As shown in the questionnaire (refer to page 4 of Appendix 5), on a scale of 1 to 5 (not influential at all, not very influential, neutral, very influential, and most influential), responses to the six labour-related factors are obtained. The average score of each labour-related factor is reported assuming all respondents answer all questions. This table provides a picture of how influential each labour-related factor is perceived to be by the respondents.

Statistical methods are then used in order to estimate population parameters from the sample statistics. The sample statistics in this situation are the percentage of responses considering that labour-related factors (individually or as a whole) are most influential considerations in AMT investment in the sample. Since these sample statistics are the estimates of the population parameters (i.e. percentage of firms in the industry that consider labour-related factors the most influential considerations in the population), a test of the hypothesis for a proportion are used. The null hypothesis is:

More than 1% of the firms consider labour-related factors most influential considerations in AMT investment (i.e. $p > 1\%$ where $100 > b > 0$)

The cumulative binomial probability can be used to test the above hypothesis.

First of all, $P(X \geq X_i | n, p)$, the cumulative binomial probability, is computed for each labour-related factor where X is the number of firms in the population, with Type I error equals to α , that consider labour-related factors the most influential consideration and X_i is a variable where $i = 0, 1, 2, \dots, 22$ for the total sample and $i = 0, 1, 2, \dots, 10$ for the CAD/CAM and robot subsamples; n is the sample size; and p is the proportion of the sample reported labour-related factors most influential consideration. Thus $t\% = (X_i/n) \times 100$.

The null hypothesis will be rejected if $P(X \geq X_i | n, p)$ is smaller than α . That is, through repeated random sampling of samples of the same size in the same population, $\alpha\%$ of the time, the sample will have more than or equal to X_i firms reported that the factor is most influential. To minimize the chance that we reject the null hypothesis when it is true, i.e. Type I error, low α values are set. Thus, if $P(X \geq X_i | n, p)$ is greater than α , the null hypothesis will not be rejected.

Having reached a conclusion as to the appropriateness of the above null hypotheses, secondary data and qualitative answers from the interview are examined in order to see if any verbal statements by respondents provide reasons to support the conclusion. Each respondent is asked to estimate the contribution of the labour-related factors (in percentage terms) to their decision to invest in AMT (see page 5 of the questionnaire). Attributes of the firms like firm size and cost of investment are used to perform correlation analysis with the percentage of investment decisions due to labour-related factors so as to uncover any relationships between these attributes and the importance of labour-related factors. The statistical test here are for the significance if the correlation measure against a null hypothesis that it is really zero.

It is also very important to examine the qualitative answers with respect to

the importance of labour-related factors from the interview. These may provide insights to explain why labour-related factors are (are not) most influential factors.

Finally, the paired sample t-test (proportion) is used to find out whether there are any difference in responses in two AMT's viz. Robot and CAD/CAM. It may, however, not be feasible to compare FMS with the other two due to its small sample size.

(2) Flexibility and (3) Status Quo Assumptions

The analysis to be performed for these two research questions are the same as that described above. The only difference is the input data. Instead of using labour-related factors from the questionnaire, "flexibility-related" and "others (status quo assumption-related)" factors are used to study the flexibility and status quo assumptions respectively. The study employs statistical tests which, again, are a test for the proportion and a correlation test.

(4) The Role of Capital Budgeting Techniques

Again, the analysis is quite similar to the above; however, the data are different. From the interview (refer to questions 4.1 to 4.11 in the questionnaire), the usage of capital budgeting techniques by the firms are uncovered and are classified into four categories. These categories are 1) not used at all, 2) used in conjunction with other methods but played a minor role, 3) used in conjunction with other methods and played an important role, and 4) used as a dominant technique.

The statistical test of a proportion are used to draw conclusion on the role of capital budgeting techniques. For example, if it is found that there is a high proportion of firms that do not use capital budgeting techniques, one can conclude that capital budgeting techniques play a very minor role in AMT decision.

Again, after the role of capital budgeting techniques is estimated, secondary

data is used to find out the relationship between some attributes (such as firm size, cost of investment) and the role of capital budgeting techniques. Since the responses to the role of capital budgeting techniques are in an ordinal scale, no correlation analysis is performed. Qualitative answers from the interview then provide reasons behind the usage of capital budgeting techniques in the industry.

5.3.2 Qualitative Analysis

If the results of the interview support the research assumption, analysis will be performed to find out why the assumption is appropriate. On the other hand, if the research assumption is not supported by the interview results, a careful examination of the samples using survey data will be done to ensure that the sample is not biased. If the sample is found to be biased in some attributes (e.g. type of product) that directly influenced the answer to the research questions (e.g. labour savings) no conclusion can be drawn as to the validity of the research assumption. However, if the sample is found unbiased, the research assumption held by current literature should be seriously questioned.

Finally, if the answers to the interviews are mixed, further analysis will be carried out to uncover whether some attributes can be used to explain the differences in the answers provided by the interviewees. These attributes include firm size, number of employees, existence of foreign markets, types of decision makers (business manager or technical manager), and types of markets and products. If it is found that there is a clear difference in answers due to one or more of these attributes, it can be concluded that the research assumption is not true for all the firms but for firms that have some common attributes. The study tries to uncover the types of relationship between the attributes that caused the differences and the research questions.

6. PATTERNS AND TRENDS OF AMT APPLICATIONS IN CANADA

6.1 Robots

In 1983, Numerical Controlled machines accounted for 4.4% of total machines in Canada while the figures in Japan and U.S. are 38% and 13% respectively. In 1984, Japan had more than 350,000 NC machines. Even after adjusting for different manufacturing sizes, Japan still had a 15 to 1 leading edge in using NC machines over Canada.

The major uses of NC machines in Canada are: machinery(39%), electronic manufacturers(8.6%), automotives(6.1%), and aerospace(5.7%). Most of the robots used in these sectors are manufactured in Japan. It is found that domestic companies are less reluctant to use robots than foreign subsidiaries in Canada. Twenty-six percent of the robot population are found in domestic firms whereas seventy-four percent in foreign subsidiaries.⁹

A study by the U.S. Department of Commerce in 1984 indicated that, as measured by number of robots per 10,000 workers, Japan, Sweden and West Germany are 2, 5, and 9 times respectively higher than Canada. This figure has indicated that the adoption of this new technology in Canada is slower than most of the major western countries. Craig and Noori (1986b) observed that "Canadian manufacturers have, without a doubt, fallen behind in adopting advanced manufacturing technology." This translates into higher per unit costs, lower productivity, poorer quality and slower market response. To become more competitive in the world market, Canadian manufacturers and labour unions have to realize that the adoption of the new technology is essential to the long term survival of Canadian manufacturing industries.

To provide a picture of robotic application in Canada, attributes of the organizations that have robot installations are analyzed. These attributes include year

of installation, type of organization (whether they are industrials, colleges and universities, or governmental and other research institutes), and type of application.

To put our focus on the application of robots in the manufacturing industries, those manufacturing firms that are using robots are studied in greater detail regarding type of manufacturing, and size, as well as ownership (foreign or domestic control).

6.1.1 A general picture

According to a recent survey by the Canadian Machinery and Metalworking Magazine, there are approximately 650 robots in use in 100 organizations in Canada. The number of robots are broken down according to the type of organization and year of installation in Table 6.1.

TABLE 6.1: CURRENT ROBOT INSTALLATIONS IN CANADA: BROKEN DOWN BY TYPE OF ORGANIZATION AND YEAR OF INSTALLATION

<u>Year of Installation</u>	<u>Industrials</u>	<u>Colleges & Universities</u>	<u>Gov't Agencies and Other Research Institutes</u>	<u>TOTAL</u>
1986*	19	5	1	25
1985	111	26	3	140
1984	58	29	11	98
1983	210	7	18	235
1982	37	4	1	42
1981	16	---	2	18
1980	52	---	---	52
1979 & Before	15	---	---	15
Cannot be determined	20	---	---	20
TOTAL	538	71	36	645

* 1986 Figures are not complete since the survey is published in May, 1986
Source: see Appendix 3

As can be seen from Table 6.1, industrial use of robots accounts for over 80% of the total robot population. Colleges and universities only actively participate in training people and partaking in robot research in the last three years. Governmental involvement in robotics had been slow. However, through the establishment of the Ontario Robotics Centre by the Ontario Centre for Advanced Manufacturing,¹⁰ the Ontario government is trying to promote the adoption of robotic technology in industry.

In fact, 11 out of the 18 robots installed in 1983 by "Government Agencies and Other Research Institutes" are for the use of the Ontario Robotic Centre.

Also shown in Table 6.1 is the year of robot installations. Over 80% of the robots currently in use were installed in the last five years. The number of robots installed in each particular year is heavily influenced by the automobile industry. For example, 43 of the 52 robots installed in 1980 were in three of the GM plants and 129 of the 235 robots installed in 1983 went into Chrysler's Windsor plant.

To better illustrate this point, Table 6.2 shows that more than half of the total robot population in Canada are employed by 10 automobile manufacturing plants of the three major automobile companies, i.e. GM, Chrysler, and Ford.

The extensive application of robotic technology has proven to be a success in the automobile industry. For example, the installation of 130 robots in Chrysler's Windsor plant in 1983 not only met its production quotas but also exceeded them. Plant capacity was estimated at 1,040 vehicles per day over two shifts. In just 25 working days on two shifts after the installation of the robots, the plant exceeded the planned production rate by 2,347 units -- more than two days worth of full production.

TABLE 6.2: APPLICATION OF ROBOTS IN AUTOMOBILE INDUSTRY

	<u>Number</u>	<u>Percentage</u>
General Motor (5 plants)	138	21.4
Chrysler (1 plant)	131	20.3
Ford (6 plants)	<u>78</u>	<u>12.1</u>
Total use by auto plants	347	53.8
Others	<u>298</u>	<u>46.2</u>
Total robot population	645	100

Source: see Appendix 3.

Also, the announcement in March, 1986 by GM to build a \$2 billion "Autoplex" facility in Oshawa to produce 720,000 mid-size vehicles a year in 1988 will boost the total robot population in Canada to well over 700, making Oshawa the

largest vehicle-production complex in North America. Thus, all projections indicate that the trend of high percentage of robots use in auto industry will continue for some time in the future. Over the past three years, however, the growth of robot installations in non-automotive manufacturing industries in Canada -- particularly electronics -- has exceeded that in autos. This can be seen by the declining percentage of total robots used in auto industry from 90% in 1977¹¹ to only 54% at present. Although more than half of the robots are used in the automobile industry, more than half of the firms that are using robots only have one robot. Thus, there are approximately 100 firms using robots. To see how the robots are used in the automobile and other industries, Table 6.3 gives the breakdown of robots by applications.

The largest single application for industrial robots in Canada is for arc welding. Other important applications include: spot welding, educational training, parts handling, and assembly. This is similar to the type of robot application in Europe¹² in which arc and spot weldings represent the largest applications.

TABLE 6.3: BREAKDOWN OF ROBOT BY APPLICATIONS

<u>APPLICATIONS*</u>	<u>RANK</u>	<u>NUMBER OF ROBOTS</u>	<u>PERCENTAGE</u>
Arc welding	1	188	21.9
Spot welding	2	169	19.7
Educational training	3	156	18.1
Parts Handling	4	130	15.1
Assembly	5	128	14.9
Others	6	35	4.0
Machine loading and unloading	7	20	2.3
Adhesive	8	13	1.5
Research	9	12	1.4
Heat treating	10	9	1.0
Cannot be determined	10	9	1.0

* Each robot may be used for more than one application.

Source: see Appendix 3.

Finally, it is found that over 90% of the robots and close to 70% of the firms that are using robots are located in Ontario even though it only accounts for about 50%

of the country's production of manufacturing goods. Details are shown in Table 6.4. This finding, however, is very heavily influenced by the automobile industry since 9 out of the 10 automobile plants are located in Ontario.

TABLE 6.4 BREAKDOWN OF ROBOTS BY PROVINCES

<u>LOCATION</u>	<u>NUMBER OF FIRMS</u>		<u>NUMBER OF ROBOTS</u>	
Ontario	71	(68%)	583	(90%)
Quebec	11	(10%)	30	(5%)
Manitoba	6	(6%)	7	(1%)
New Brunswick	6	(6%)	6	(1%)
B.C.	5	(5%)	14	(2%)
Alberta	4	(4%)	1	(-)
TOTAL	105	100%	645	100%

Source: See Appendix 3.

6.1.2 Robots In Manufacturing Industries

(1) By Industrial Sector

As indicated in Table 6.5, a total of 77 firms in different industries are using robots and 56 are manufacturing firms. This indicates that the primary application of robotic technology in industry is the manufacturing sector.

TABLE 6.5: ROBOT INSTALLATIONS BY INDUSTRIES

<u>INDUSTRIAL TYPE</u>	<u>NUMBER OF FIRMS</u>
Manufacturing	56
Transportation, Communication, and other public utilities	2
Wholesale Trade	2
Finance, Insurance and Real Estate	2
Service and Repair Businesses	1
Cannot be determined	14
TOTAL	77

Source: see Appendix 3.

These 56 manufacturing firms can be further classified into different categories. They are depicted in Table 6.6. Since firms are classified according to the product code, some firms may produce products in more than one category, thus, the total number of firms in Table 6.6 does not equal to 56.

From Table 6.6, one can see that manufacturers of the transportation equipment, fabricated metal products, and machinery are the major users of robots. This is due to the unpleasant and dangerous working environment, the requirement to handle heavy materials, and the need for high precision output. Thus, robots can fit into their production process quite nicely.

TABLE 6.6: DISTRIBUTION OF ROBOTS BY DIFFERENT SECTOR OF THE MANUFACTURING INDUSTRIES

<u>Type of Manufacturing</u>	<u>Number of Firms</u>
Transportation Equipment	19
Fabricated Metal Products, except Machinery and Transportation Equipment	15
Machinery, except Electrical	11
Electrical and Electronic Machinery, Equipment and Supplies	10
Primary Metal Industries	7
Measuring, Analyzing and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks	4
Furniture and Fixtures	3
Petroleum Refining and Related Industries	2
Rubber and Miscellaneous Plastics Products	2
Stone, Clay, Glass and Concrete Products	2
Miscellaneous Manufacturing Industries	2
Chemical and Allied Products	1

Source: see Appendix 3.

TABLE 6.7: USE OF ROBOTS AND SIZE OF FIRMS BY SALES AND EMPLOYEES

<u>Annual Sales</u>	<u>Number of Firms</u>	<u>Number of Employees</u>	<u>Number of Firms</u>
\$250,000 - \$1million	3	Less than 25	1
\$1 - \$5 million	4	Between 25 and 49	1
\$5 - \$25 million	7	Between 50 and 99	7
\$25 - \$100 million	13	Between 100 and 199	5
Over \$100 million	19	Between 200 and 499	8
Not Available	10	Between 500 and 999	7
		Over-1000	21
TOTAL	56	Not Available	6
		TOTAL	56

Source: see Appendix 3.

(2) By Size

Consistent with the survey study by Craig and Noori (1986b),¹³ it is found that most of the firms with robots are quite large. As shown in Table 6.7, only a few firms using robots can be considered small firms (annual sales less than \$5 million

and number of employment less than 100 people). Therefore, it can be concluded that firms that are most likely to use robots are those that have over \$100 million in sales and employ more than 1000 employees.

TABLE 6.8: USE OF ROBOT BY FIRM'S OWNERSHIP

		<u>Number of Firms</u>
Fully-owned subsidiary of:		
U.S.	23	
England	1	
Others	2	26
Fully-controlled by:		
U.S.	3	
Others	2	5
Strong Influence by (20-49% foreign owned):		
U.S.	3	
England	1	4
Canadian Owned		9
Data Not Available		12
TOTAL		56

Source: see Appendix 3.

(3) By Ownership

As can be seen in Table 6.8, less than half of these 56 firms are controlled by Canadians. Twenty-six firms are fully-owned subsidiaries of foreign, mostly U.S., corporations or investors. Five firms are fully-controlled (more than 51% owned by foreign corporations or investors) by foreigners. The remaining 25 firms are possibly Canadian-owned or Canadian-controlled companies.¹⁴

6.1.3 Cross-country Comparison

When these figures are compared with those of the other industrialized nations, it can be seen that Canada is lagging behind many of them, most notably, Japan, Sweden, and the U.S. even after adjusting for the size of manufacturing sectors. For instance, U.S. has over 10,000 robots currently in use. Given that the size of U.S. manufacturing sector to that of the Canadian is about 10 to 1, one may suspect that Canada should have more than 1,000 robots in use. However, the actual number is just

about half of what might have been predicted. Table 6.9 gives a picture of robot installations in different countries.

Japan has 32.1 per 10,000 factory workers and Sweden has 20.2¹⁶. Canada, with 3.7 robots per 10,000 persons in manufacturing, trails behind even Czechoslovakia, which has 7.2 per 10,000 persons. These figures further substantiate that Canada is lagging behind other industrialized nations in the adoption of robots.

The lag is probably caused by high capital costs which make justification for robots very difficult, and the relatively limited sophistication of the first generation robots. It is estimated that first generation robots could be used to perform only a maximum of 3% of all industrial tasks.¹⁷ The more sophisticated next generation of robots, which are now being introduced, can perform wider types of tasks such as assembly and various semi-skilled works. Job security is becoming a major barrier to the introduction of these robots on the factory floor. A West German study estimates that a loss of five to ten jobs for each second-generation robot installed, versus 2.5 jobs lost to each first-generation robot.¹⁸

TABLE 6.9: WORLDWIDE INSTALLATION OF ROBOTS

<u>COUNTRY</u>	<u>TOTAL ROBOTS IN:</u>			
	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1985</u>
Japan	6,000	10,000	20,000	30,000
U.S.A.	3,200	5,000	8,200	12,000
Sweden	1,200	1,800	1,900	2,800
W. Germany	1,100	2,200	4,500	6,500
Italy	400	550	1,800	2,300
England	380	700	1,700	2,300
France	100	210	1,300	2,100
Canada	113	155	388	525
Rest of W. Europe	450	550	650	750
Eastern Block	520	600	650	1,000

Source: British Robot Association and Canadian Machinery and Metal Working Magazine.¹⁵

6.2 CAD/CAM

The major advantage of CAD/CAM is its flexibility which enables companies to

have faster design and production time to meet the continual changes in demand from the customers. However, some of the Canadian manufacturers are running the risk of becoming non-competitive because other countries are heavily subsidizing the introduction of automated assembly and production control technologies. Fortunately, a study by the Canadian Institute of Metalworking indicated that awareness, knowledge, development and application of CAD/CAM tends to be filtering down, over time, from large to medium and small size firms.

To give a general picture of CAD/CAM applications in Canada, the following sections analyze the attributes of organizations using CAD/CAM. These attributes are similar to those that are used to analyze robot applications in Canada. Again, the manufacturing industry is singled out for more indepth study.

6.2.1 A general picture

In Canada, 238 companies reported that a CAD/CAM systems have been installed in their plant.¹⁹ Similar to the robots, the majority of the CAD/CAM systems (78%) have been installed in the last five year. This is shown in Table 6.10.

Unlike robots, it is quite uncommon for an organization to have more than one CAD/CAM system. The only exceptions are educational and research institutes which use several systems for training and research purposes.

Table 6.10 also shows that industrial use of CAD/CAM accounts for over 70% of the total uses. Similar to the robots, the other two groups only actively participated in adopting CAD/CAM recently.

CAD/CAM has been used for many purposes. The most common applications include 1) mechanical engineering and manufacturing; 2) electrical and electronic engineering; 3) structural analysis and civil engineering, architecture; and 4) integrated CAD/CAM, e.g. generation of NC machine tapes and cutter paths or common

data bases for integrated CAD/CAM. Table 6.11 shows how CAD/CAM systems in Canada are put to use. By far, most of them are integrated CAD/CAM. Again, a system can be used for more than one function, thus, the total does not add up to 238 in Table 6.11.

TABLE 6.10: CURRENT CAD/CAM INSTALLATIONS IN CANADA: BROKEN DOWN BY TYPE OF ORGANIZATION AND YEAR OF INSTALLATION

<u>Year of Installation</u>	<u>Industrials</u>	<u>Colleges & Universities</u>	<u>Gov't Agencies or other research institutes</u>	<u>TOTAL</u>
1986*	15	1	1	17
1985	32	11	1	44
1984	44	6	7	57
1983	22	13	15	50
1982	10	6	1	17
1981	20	3	2	25
1980	13	---	---	13
1979 & Before	12	1	---	13
Cannot be determined	<u>1</u>	<u>1</u>	<u>---</u>	<u>2</u>
TOTAL	169	42	27	238

* 1986 Figures are not complete since the survey was published in May, 1986.

Source: see Appendix 3.

TABLE 6.11: CAD/CAM BY APPLICATIONS

<u>APPLICATION</u>	<u>NUMBER</u>	<u>PERCENTAGE</u>
integrated CAD/CAM	182	49.5
mechanical engineering and manufacturing	121	32.9
electrical and electronic engineerings	37	10.1
structural analysis and civil engineering, architecture	<u>28</u>	<u>7.6</u>
TOTAL	368	100.0

Source: see Appendix 3.

TABLE 6.12: NUMBER OF APPLICATIONS OF THE CAD/CAM SYSTEMS

<u>NUMBER OF APPLICATIONS</u>	<u>NUMBER OF FIRMS</u>	<u>PERCENTAGE OF FIRMS</u>
1	135	56.7
2	56	23.5
3	27	11.3
4	10	4.2
Cannot be determined	<u>10</u>	<u>4.2</u>
TOTAL	238	100.0

Source: see Appendix 3.

Among these 4 applications, most of them (57%) are dedicated to only one

application (see Table 6.12). Only one of the organizations that is reported to use the system for all four purposes is an industrial user. Others are mainly in the "Colleges and Universities" group.

In terms of location, the majority of firms are located in Ontario (see Table 6.13). If one only considers the industrial users, the percentage goes up from 61.3% to 70%.

TABLE 6.13: LOCATION OF FIRMS HAVING CAD/CAM SYSTEMS

Location	Number of Firms	Percentage of Firms
Ontario	146	61.3%
Quebec	50	21.0
B.C.	11	4.6
New Brunswick	10	4.2
Manitoba	9	3.8
Alberta	8	3.4
Nova Scotia	3	1.3
Saskatchewan	1	0.0
TOTAL	238	100.0

Source: see Appendix 3.

6.2.2 CAD/CAM in manufacturing industries

(1) By Industrial Sector

Based on a survey by the Canadian Manufacturer's Association,²⁰ it is found that manufacturing industries have absorbed 50% of the total technological impact of CAD/CAM. Table 6.14 supports these findings, as the number of manufacturing firms (115) accounts for roughly half of the total number of CAD/CAM installations (238). The table also shows that manufacturing accounts for three quarters of the total number of CAD/CAM systems for industrial uses.

The use of CAD/CAM in manufacturing industries is further analyzed in Table 6.15. Again, firms can be classified into more than one category. Similar to robots, producers of machinery, fabricated metal products and transportation equipment are the major users of CAD/CAM.

TABLE 6.14: CAD/CAM INSTALLATIONS BY INDUSTRIES

<u>Industrial Type</u>	<u>Number of Firms</u>
Manufacturing	115
Wholesale Trade	2
Service and Repair Businesses	2
Transportation, Communication, and other public utilities	1
Finance, Insurance and Real Estate	1
Construction	1
Cannot be determined	31
TOTAL	153

Source: see Appendix 3.

TABLE 6.15: DISTRIBUTION OF CAD/CAM BY DIFFERENT SECTOR OF THE MANUFACTURING INDUSTRIES

<u>Type of Manufacturing</u>	<u>Number of Firms</u>
Machinery, except Electrical	73
Fabricated Metal Products, except Machinery and Transportation Equipment	23
Transportation Equipment	21
Electrical and Electronic Machinery, Equipment and Supplies	18
Primary Metal Industries	8
Measuring, Analyzing and Controlling Instruments; Photographic, Medical and Optical Goods; Watches and Clocks	7
Rubber and Miscellaneous Plastics Products	6
Miscellaneous Manufacturing Industries	5
Stone, Clay, Glass and Concrete Products	2
Chemical and Allied Products	1

Source: see Appendix 3.

(2) By Size

Again, as shown in Table 6.16, more large firms apply CAD/CAM than small firms. However, the contrast is not as sharp as in the case of robots since there is a large number of medium size firms (with sales between \$5 to \$25 million) using CAD/CAM. This may indicate that the CAD/CAM technology has been assimilated from large to medium size firms. Also, it may indicate that the price of a CAD/CAM system is cheaper than that of the robot system and medium size firms are able to afford it. The employment figures shown in Table 6.16 also support that medium size firms are employing CAD/CAM as often as the larger ones.

TABLE 6.16: USE OF CAD/CAM AND SIZE OF FIRMS BY SALES AND EMPLOYEES

<u>Annual Sales</u>	<u>Number of Firms</u>	<u>Number of Employees</u>	<u>Number of Firms</u>
\$250,000 - \$1million	3	Less than 25	13
\$1 - \$5 million	13	Between 25 and 49	12
\$5 - \$25 million	30	Between 50 and 99	12
\$25 - \$100 million	23	Between 100 and 199	15
Over \$100 million	24	Between 200 and 499	25
Not Available	<u>22</u>	Between 500 and 999	17
TOTAL	115	Over 1000	19
		Not Available	<u>2</u>
		TOTAL	115

Source: see Appendix 3.

(3) By Ownership

From Table 6.17, less than half of the firms that are using CAD/CAM are controlled or owned by foreigners. This is consistent with the previous analysis which found that many medium size firms are using CAD/CAM. Most of the foreign subsidiaries in Canada are large, e.g. GM, Westinghouse, and most of the Canadian-owned companies are small to medium size. Thus, there is a high positive correlation between the size of the firm and the likelihood of foreign ownership.

TABLE 6.17: USE OF CAD/CAM BY FIRM'S OWNERSHIP

		<u>Number of Firms</u>
Fully-owned subsidiary of:		
U.S.	28	
England	3	
Others	<u>4</u>	35
Fully-controlled by:		
U.S.	3	
England	6	
Others	<u>5</u>	14
Strong Influence by (20-49% foreign owned):		
U.S.	2	
England	1	
Others	<u>2</u>	5
Canadian Owned		26
Data Not Available		<u>35</u>
TOTAL		115

Source: see Appendix 3.

From the above analysis, it can be seen that CAD/CAM technology is slowly

assimilated by the smaller firms. However, the growth rate is still lagging behind. The worldwide application of CAD/CAM technology is expected to accelerate by an average of 46% per year whereas the rate in Canada is only 37%.²¹ These statistics tell quite starkly that foreign competitors are applying advanced manufacturing technologies at a much quicker pace than domestic manufacturers.

6.3 FMS

During the last few years, flexible manufacturing technology has become very popular in the industrialized countries of the world. Although, the technology originated in the U.S. in the mid 1960s, since then it has spread to many other countries. Today there are approximately 370 FMS operating from the U.S. to the U.S.S.R. In Canada, only a few firms can claim to have FMS.

6.3.1 A general picture

Only nine firms are identified as having FMS installations. An example is General Motors of Canada Limited in Oshawa, which has a multi-million dollar investment in FMS. Other companies include Dominion Textile, IBM Canada, Pratt and Whitney Canada, Caterpillar Canada, Allen-Bradly Company, Bata, Northern Telecom, and Canadian General Electric.

The characteristics of these companies are depicted in Table 6.18. It can be seen that all firms having FMS are quite large. According to the ranking by the Blue Book of Canadian Business, seven out of the nine companies are in the top 500 Canadian companies and most of them in the top half of the list. Their sales are well above \$100 million a year. Thus, one can easily conclude that only large firms can afford such an expensive and long term project.

It can also be seen that two thirds of the companies are U.S. subsidiaries and only Bata, Dominion Textile, and Northern Telecom are Canadian-owned companies.

However, this is not surprising since most of the large manufacturing companies in Canada are foreign subsidiaries.

TABLE 6.18: CHARACTERISTICS OF FIRMS HAVING FMS

<u>Name of the co.</u>	<u>Sales(\$m)</u>	<u>Rank*</u>	<u>Employees</u>	<u>Major Shareholder (% ownership)</u>
Allen-Bradly	>100	N/A	878	Rockwell International of U.S (100)
Bata	163	N/A	180	N/A
Cdn. G. E.	1,494	58	11,605	General Electric of U.S. (92)
Caterpillar Canada	277	2/8	544	Caterpillar Finance of U.S. (100)
Dominion Textile	926	119	10,500	N/A
GM of Canada Ltd.	18,993	1	48,100	General Motor Corp. of U.S. (100)
IBM Canada	3,148	26	12,373	IBM World Trade of U.S. (100)
Northern Telecom	5,818	11	46,500	Bell Canada Enterprise (52)
Pratt Whitney Cda	749	122	7,767	United Technologies of U.S. (98.1)

* Ranking by the Blue Book of Canadian Business

Source: see Appendix 3.

In terms of product type, seven of these firms are equipment and machinery manufacturers and the other two are producers of footwear and textile mill products respectively. A brief profile of each firm is depicted in Table 6.19. It can be seen that all of these firms are industrial leaders of their industry. The FMS projects are very costly and require a long planning and implementation time. For example, Pratt and Whitney Canada is taking 10 years and \$95 million to build the first phase of a FMS in Halifax and is expected to be completed in 1988. The final phase is scheduled to be completed not until 1991. Dominion Textile has invested \$17.5 million and have recently invested \$15 million more in this state-of-the-art technology.

Most of these firms see that FMS is a big step in a gradual transformation of all the company's manufacturing operations into Computer Integrated Manufacturing. These modernization programs are usually driven by the conviction that CIM is the only way in which the company can expand its capacity and responsiveness, and keep an edge in cost, quality, and productivity over its competition. As Dennis Godfrey,²² President of Dominion Textile, states, "installation of this new technology will improve quality, productivity, and flexibility."

TABLE 6.19: PROFILE OF FIRMS USING FMS

<u>Firm</u>	<u>Industry</u>	<u>Profile</u>
Allen-Bradly:	1	Large manufacturer of industrial automation system and control.
Bata:	4	Largest footwear manufacturer and retailer in Canada.
Canadian G. E.:	1	Largest manufacturer of electrical and related equipment in Canada and it also provides technical and distribution services to complement its products.
Caterpillar Canada:	2	World's leading maker of construction machinery. Large manufacturer of material handling equipment including wheel loaders, log skidders, and lift trucks.
Dominion Textile:	5	Largest Canadian manufacturer of textile and related products with worldwide manufacturing and sales activities.
G. M. Canada:	3	Largest manufacturer of transportation equipment in Canada. It involves in the manufacturing, assembly and distribution of products which relate to transportation equipment principally of cars, trucks, coaches, and locomotives as well as parts and accessories.
IBM:	2	Largest manufacturer and distributor of personal and business computers and other business equipment. Major operations are in the field of information handling systems and services to help solve the increasingly complex problems of business, government, science, education, and other areas of human activity.
Northern Telecom:	1	Canada's largest and North America's second largest designer and manufacturer of telecommunication equipment (sixth largest in the world). Other products include computer terminals and peripheral equipment primarily to telecommunication industry.
Pratt and Whitney:	3	Large manufacturer in design, development, and manufacturing of small gas turbine engines for general aviation and regional transports.

1=Electrical and Electronic Machinery, Equipment and Suppliers;

2=Machinery, except Electrical; 3=Transportation Equipment;

4=Leather and Leather Products; and 5=Textile Mill Products.

Source: see Appendix 3.

In sum, FMS in Canada is still in its infancy and only a few large enterprises are able to afford this "factory of the future." The success or failure of these firms is of importance to the Canadian economy since most of these firms are heavily involved in export. For example, 75% of Northern Telecom's sales are outside Canada. The figures for Pratt & Whitney, General Motor of Canada, Dominion Textile, IBM Canada, and Canadian General Electric are 72%, 53%, 38%, 29%, and 13% respectively. Thus, their success will lead to an increase in export earnings as well as more employment for Canadians.

6.3.2 International development

Although Canada lags behind in both CAD/CAM and robot uses, its FMS installations can be compared with the rest of the industrialized nations after adjusting for the size of the manufacturing sector. A comparison of FMS installation worldwide is presented in Table 6.20.

TABLE 6.20: FMS INSTALLATION AROUND THE WORLD*

<u>COUNTRY</u>	<u>NUMBER</u>	<u>PERCENTAGE</u>
<u>Western Countries:</u>		
U.S.A.	70	18.5
Japan	70	18.5
West Germany	30	7.9
U.K.	30	7.9
France	25	6.6
Italy	25	6.6
Canada	9	2.4
Sweden	8	2.1
Others in W. Europe	6	1.6
<u>Soviet Bloc:</u>		
U.S.S.R.	60	15.8
East Germany	20	5.3
Others in E. Europe	26	6.9

* SOURCE: Raju, Venkitakwamy "FMS Around the World: A Status Report," Conference Paper, Flexible Manufacturing Systems'86, March, 1986, Chicago, Illinois.

Thus, Canada can be considered as one of the leading industrialized nations in FMS adoptions. However, most of the components of the FMS are imported from other countries. These countries include Japan, the U.S., and Sweden. To be competitive in the long term, it is to the interest of Canadian manufacturing industries to develop FMS technology of its own instead of relying on the transfer of technology through the parent corporations in the U.S., and other countries.

7. SAMPLE DESCRIPTION

Following the methodology described in Section 5.2, 22 firms are interviewed. Table 7.1 contains descriptive data on the firms who agreed to participate in the study.

As shown, the samples selected are quite representative of the population. The size of the CAD/CAM firms are generally smaller than the robotic firms but the distributions of firms of CAD/CAM and robot are similar to that of their populations. In terms of types of manufacturing, the majority are equipment and machinery manufacturers in all three technology categories.

More than half of the robot firms are subsidiaries of U.S. public companies and only two are Canadian-owned. The other two are joint ventures between foreign and domestic firms and between two foreign firms. Nine out of ten of the CAD/CAM firms are Canadian owned and the remaining is owned by a U.S. investor.

In terms of types of production, sixty percent of the firms produce mainly custom-made products and only forty percent engage in mass production. Since the CAD/CAM firms tend to be smaller, they are usually non-unionized whereas the robotic firms are usually unionized.

In terms of application, six firms use their robots for welding and two firms use them for loading and unloading. The remaining applications are heat treating, assembly, and parts handling. For CAD/CAM, all but one are integrated systems.

A complete list of background information about these firms are shown in Appendix 6 and 7 for interested readers. Appendix 6 shows the background information of the CAD/CAM firms whereas Appendix 7 shows the background information of the robot firms.

TABLE 7.1: DESCRIPTIVE STATISTICS OF THE SAMPLE**1) Size by Employees**

<u>Number of Employees</u>	<u>Number of Firms (%)</u>	<u>CAD/CAM</u>	<u>ROBOTS</u>
Less than 25	1 (4.5%)	1	0
Between 25 and 49	3 (13.6%)	2	1
Between 50 and 99	2 (9.1%)	1	1
Between 100 and 199	5 (22.7%)	4	1
Between 200 and 499	3 (13.6%)	0	4
Between 500 and 999	4 (18.2%)	2	1
Over 1000	4 (18.2%)	0	2
TOTAL	22 (100%)	10	10

2) Size by Sales

<u>Annual Sales</u>	<u>Number of Firms (%)</u>	<u>CAD/CAM</u>	<u>ROBOTS</u>
Less than \$5 million	3 (13.6%)	4	0
\$5 - \$25 million	6 (27.2%)	4	1
\$25 - \$100 million	3 (13.6%)	2	3
Over \$100 million	6 (27.2%)	0	4
Not Available	2 (9.1%)	0	2
TOTAL	22 (100%)	10	10

3) Types of Manufacturing

<u>Type of Manufacturing</u>	<u>Number of Firm</u>	<u>CAD/CAM</u>	<u>ROBOTS</u>
Machinery, except Electrical	10	5	4
Transportation Equipment	8	2	5
Electrical and Electronic Machinery, Equipment and Supplies	7	3	3
Fabricated Metal Products, except Machinery and Transportation Equipment	6	3	3
Rubber and Miscellaneous Plastics Products	2	2	0
Primary Metal Industries	2	0	2
Furniture and Fixtures	1	0	1

TABLE 7.1 DESCRIPTIVE STATISTICS (CONT'D)

4) Ownership

<u>Type</u>	<u>Number of firms (%)</u>	<u>CAD/CAM</u>	<u>ROBOTS</u>
<u>Canadian-owned:</u>			
Owner/Manager	3 (13.6%)	2	1
Family	3 (13.6%)	3	0
Partners	1 (4.5%)	1	0
Public	3 (13.6%)	2	1
<u>U.S.-owned:</u>			
Individual	1 (4.5%)	1	0
Public (Subsidiary of)	8 (36.3%)	0	6
<u>Joint-Venture:</u>			
Two foreign firms	1 (4.5%)	0	1
One Canadian and one foreign	1 (4.5%)	0	1
<u>Not available</u>	<u>1 (4.5%)</u>	<u>1</u>	<u>0</u>
TOTAL	22 (100%)	10	10

5) By production method

<u>Type of production</u>	<u>Number of firms (%)</u>	<u>CAD/CAM</u>	<u>ROBOT</u>
Custom	13 (59.1%)	6	7
Standard	<u>9 (40.1%)</u>	<u>4</u>	<u>3</u>
TOTAL	22 (100%)	10	10

6) By union status

<u>Status</u>	<u>Number of firms (%)</u>	<u>CAD/CAM</u>	<u>ROBOT</u>
Unionized	10	7	1
Non-unionized	8	1	7
Not Available	<u>4</u>	<u>2</u>	<u>2</u>
TOTAL	22	10	10

8. AMT DECISION MAKING PROCESS

One of the major objectives of this study is to understand the decision making process of AMT investment. Through the discussion with the interviewees, a rich database is generated for such a purpose.

The database allows the identification of factors that have impact on the AMT decisions. Also, the complexity of these decision processes cannot be studied systematically nor can they be compared and contrasted against one another if they are not simplified. Therefore, with the help of organizational behaviour studies on decision making processes, the AMT decision processes are decomposed into several stages. A general model is then derived by analyzing the stages that each firm has gone through. It is believed that all the firms in the sample can be described by this general model. By careful studying of these decision processes, patterns are detected. Five specific models are then developed to explain the five different patterns of firms in the sample.

8.1 Factors Impacting AMT Investment decision

FIGURE 8.1 ELEMENTS IN THE FIRM'S DECISION TO INVEST IN AMTs

From the interviews, four major elements can be identified as having major impacts on the decision to invest in AMTs. These elements are: external environment, internal environment, government, and supplier. Figure 8.1 gives a graphical presentation of how these elements exert influence on the decision to invest in AMTs. As there was no attempt to structure the request for these factors, the interviewees supplied a wide range of thoughts on the factors impacting their decision to invest in AMTs that turned out to be very revealing.

External Environment

Table 8.1 lists five typical factors that have impact on the firm's decision to invest in AMTs. Some firms reported more than one factor whereas others reported none. The latter case implies that external environment does not have significant impact on the decision. A total of 14 firms reported that one or more external factors triggered their investigation on the AMT investment.

TABLE 8.1 EXTERNAL FACTORS IMPACTING AMT DECISION

<u>FACTORS</u>	<u>NUMBER OF FIRMS</u>
1. Availability of AMTs	7
2. Increase in competition	6
3. Customer's changing production technology	5
4. Shorter product life cycle	4
5. The existence of powerful customers	2

Detailed analysis of interview results reveal that AMT advancements seem to be the most important external factor in motivating firms to invest in them.

The increase in competition in both domestic and foreign markets also exert significant influence on the firms. Many of the firms' competitors have adopted some kinds of new technology to cut cost and to improve product quality and variety. The firms come to recognize that investing in AMTs would enhance the chance of future survival.

In recent years, many large machinery and transportation equipment manufacturers have applied inventory reduction technologies such as Just-In-Time technology. This means that they demand their suppliers to provide parts and components on short notice and in the desired amount which can fluctuate greatly. As most of the firms in the sample are producing parts and components for these large firms, they have to meet their stringent demands for delivery schedule, quantity, and quality in order to obtain long term contracts. Thus, customer's changing production technology is an important factor in pushing the firms to adopt AMTs.

The average product life cycles have been shortening at an alarming rate: from 15 years in the past decade to 12 to 18 months today. This renders the investment in dedicated machines very risky. It is because the products produced by the dedicated machines cannot cover the costs of the machine due to the short product life cycle. These machines become obsolete at the end of the product life cycle. Thus, over 80% of the sample use less than 2-year payback period to measure their investment proposal. Consequently, investment in AMTs become a wise choice since they usually can be used to produce a variety of products, and when one product has become obsolete, the machine can be used to produce another product.

Finally, some firms reported that the presence of powerful customers exert direct influence on their decisions.

Internal Environment

Table 8.2 identified twelve internal factors that have impact on the firm's decision to invest in AMTs.

Large equipment manufacturers are striving for new production technology, such as JIT, to reduce production cost, and to cope with the shortening of product life

cycle and increasing competition. These changes have led to a changing demand for faster response rate, better quality and price from their parts and components suppliers. Fourteen firms expressed that they have a strong desire to meet the changing needs of their customers, since this is vital for their survival.

TABLE 8.2 INTERNAL FACTORS IMPACTING AMT DECISION

FACTORS	NUMBER OF FIRMS
1. Need to meet the changing customer demands: faster response rate, better quality; and better price	14
2. Desire to capture opportunity (new product, increase in production)	10
3. Concern over labour cost	9
4. Need for higher flexibility	7
5. Believe in AMTs by the top management	6
6. Fail to perform certain job by current equipment	4
7. Need to increase the productivity of scarce resources--skilled labours	4
8. Compete with other divisions of the company	3
9. Need to be perceived as "hi-tech" producers (marketing and psychological reasons)	2
10. Minimize the reliance on skilled labour	2
11. Replace the retiring equipment	2
12. Need to keep abreast with technology	1

"Desire to capture opportunity" is another important factor. Ten firms felt that they have a strong desire to produce more or to venture into a new product line. These desires have led them to conclude that AMTs can help them to achieve their goals.

A concern over labour cost is a very important factor. For some firms, labour costs are still in the order of 40-60% of the total manufacturing costs. Moreover, the unionized nature of many firms has increased the labour rate significantly. For these firms, finding ways to cut labour costs is in the top priority of the management.

In addition to the above three factors, the need for higher flexibility and top management's belief in AMTs are also crucial internal factors for some firms. Due to the increase in competition and the push for zero-inventory production by the industrial customers, the volatility of demand increases. In other words, it is essential that suppliers have the ability to vary the production volume significantly in a short period of time or they have to build a large inventory as a buffer. In a competitive

world where inventory is very costly, many firms are seeking to cope with the high demand volatility by increasing the flexibility of their production line. They gradually recognize the ability of AMTs to help them to achieve this goal.

In some small-and-medium size firms where the manager is the owner, the investments in AMT are sometimes strongly influenced by the owner's own desire. The owner/manager of these firms has strong personal desire to acquire the new technologies. These investments may not have a proper justification; however, their own preferences are enough to expedite the AMT investments. In the large firms, top management may have a strong vision that AMTs are the production technologies of the future. In order to get ahead of the competitors, they may decide to acquire AMTs with or without proper justification.

The other factors mentioned by some firms are listed in Table 8.2. Since these factors are not frequently mentioned, they do not warrant further discussion here.

Government

The role of government in the adoption of AMTs can be in the form of financial and technical assistance. Both federal and provincial governments provide financial assistance to firms adopting new technology. For example, financial assistance is provided under the Industrial and Regional Development Program (IRDP).

In addition to financial assistance, the Ontario Centre for Advanced Manufacturing is set up to help Ontario companies to respond to the critical challenges of improving productivity and competing internationally.

Two technology centres were established under OCAM: the Ontario CAD/CAM Centre and the Ontario Robotic Centre. These centres have the mission to accelerate the utilization of CAD/CAM and robotics through programs promoting awareness and programs promoting applications, and to encourage the growth of supportive CAD/CAM

and robotics industries in Ontario.

Some firms in the sample have taken advantage of the centres. In particular, a manufacturer of brake and electrical parts for heavy trucks has acquired robots with the help of Ontario Robotic Centre. The centre provided a no obligation feasibility study for the firm as well as technical assistance in the selection of robots. Coupled with financial assistance from IRDP, the firm had a successful implementation of robots.

Suppliers

Japan, the U.S., Sweden, West Germany, and Italy are the world leaders in the development, production, and end use of industrial robots and CAD/CAM systems. The R&D costs involved in the development of a successful system represent a large percentage of total costs. Thus, suppliers are very aggressive in order to generate sales to cover the fixed R&D costs. A number of the major international suppliers have set up representative offices in Canada concentrated in the Montreal and Toronto areas. These representative offices are very active in inducing companies to go for AMTs.

Their activities include visiting potential customers, responding to the request for proposals from customers, training of operators, and post-sale technical assistance.

The activities of the suppliers exert significant influence in the firm's decision to acquire AMTs. It is because AMTs are not a product that can be purchased and used immediately, they require a lot of support from the supplier before and after the implementation. Thus, the decision to acquire AMTs heavily depends on the ability of the suppliers to provide training and technical assistance to the customers.

8.2 The stages of decision making process

The decision making process is evoked when a combination of the above four factors reach a threshold. The importance of each factor in evoking the decision making

process can be very different across firms. Each firm has a specific combination of these factors that represent a stimulus.

Decision making process can be defined as a set of actions and dynamic factors that begins with the identification of a stimulus for actions and ends with the specific commitment to action. The importance of decision making for the study of organizations has been recognized by the organizational behaviour researchers. However, it is found that no current literature has directly dealt with the decision making process of investment in AMTs. A few key organizational behaviour studies about how managers make decisions provide a guideline for the study of AMT decision making process.

Mintzberg, Raisinghani, and Theoret (1976) have classified patterns found in decision making processes. They called them recognition, diagnosis, development (in the form of design and search), and selection (comprising choice procedures and authorization) stages. The design and search steps were used to create custom-made and modified solutions, to identify a ready-made solution, and to sanction a fully developed solution that was available when the process began. The Mintzberg, Raisinghani, and Theoret study made a major contribution by identifying the key stages of decision making and external factors that influence the process.

Nutt (1984) divided the decision process into five stages: formulation, conceptualization, detailing, evaluation, and implementation. Two criteria are used in classifying 78 decision processes employed by different organizations. The two criteria are: the stability and the clarity of the distinctions. A stable classification has within-category similarities and between-category differences that can be explicitly specified. The clarity criterion required that the distinctions among these categories have theoretical as well as practical significance. Five process types are identified using these two criteria. These five process types have significant differences in the

five stages of the decision process. For example, a process type called the historical model has only the formulation, detailing and implementation stages whereas another process type called Nova has all the stages.

These two studies provide some valuable insights into the decision process of the organizations. However, one cannot generalize their results and assume that AMT decision process follows the same patterns. Although Mintzberg, Raisinghani, and Theoret's study uses a diverse sample (manufacturing, service, government, and institution), the sample size is too small to have a high degree of external validity. In other words, results cannot be generalized across population, settings, and other similar conditions. This also holds true for Nutt's study because his study, although using a larger sample, only concentrated on the service industry.

Since this study concentrates on the decision process of manufacturing firms in acquiring AMTs, the findings of the above two studies may not be directly applicable. However, Mintzberg, Raisinghani, and Theoret's key stages can be used to reduce each AMT decision process to a sequence of routines. The use of a flow chart approach is also very useful in this study to provide a graphical representation of each decision process. Careful analysis of these routines and flowcharts yield a general model. Keeping in mind Nutt's two criteria in identifying process types, five process types are subsequently derived from the 22 samples.

The AMT decision process is made up of a set of activities that begins with the identification of an opportunity or a need and ends with the decision of whether to invest in AMTs. To classify these activities, a framework can be imposed or patterns in the activities allowed to emerge from an examination and comparison of the cases. The emergent approach is used by Mintzberg, *et al.* to examine a small sample of cases. Using intuition, they organized decision activities into patterns that describe the

nature and sequence of key stages and within-stage steps. Since the number of cases in this study (22) is similar to that of theirs (25), their stage classifications are very useful in identifying patterns of decision process in this study.

Table 8.3 provides a detailed list of activities of the cases in different stages. Size ranks, cost of investment ranks, and internal and external factors that caused the investments of each case are also presented to provide a deeper insight into the decision process as well as the commonalities and differences among different cases. In addition to the firm size and the stimulus, type of decision, stages, and routines are described in detail in the following subsections.

Firm Size and Decision Process

The samples are ranked in ascending order according to the number of employees. This is shown in the second column of Table 8.3. Previous research has shown that the complexity of the decision process increases with the size of the firm. The result of this study is consistent with previous studies: a positive relationship exists between firm size and the complexity of decision process. However, the relationship is found to be indirect. For instance, small firms tend to be owner/manager type. The owner/manager can make decisions without seeking authority and the evaluation process is based on judgment rather than quantitative analysis. Also, these individuals are often engineers and are not trained to use the qualitative financial evaluation techniques. Thus, the decision process is usually more simple in the owner/manager type of organizations.

The cost of the investment may directly affect the decision process. For small investments, lower level management can make decisions without the approval of the top management. For investment of significant size, a more elaborate decision process is used. In a small firm, this kind of investment decision is made by the owner or the

TABLE 8.3: DECISION PROCESS OF THE SAMPLE

Firm	Size Cost		Stimulus		Type	Solution Identification			Detailing		Evaluation	
	Bank	Bank	Internal	External		Decision	Diag-	Solution	Auth. of	Study	Screen-	Just.
1	22	13	1	2,5	opp	x	x	x	x	x	x	x
2	14	5	3,2	1,3,5,11	prob	x	x	x	x	x	x	x
3	18	15	1,2	1,2,4,7	prob	x	x	x	x	x	x	x
4	16	17	1,3	1,4,6	opp/prob	x	x	x	x	x	x	x
5	12	14	1	1,3,6,7	prob	x	x	x	x	x	x	x
6	20	7	1,3	1,3,4	prob	x	x	x	x	x	x	x
7	15	20	1,3	1,2,9,10	opp	x	x	x	x	x	x	x
8	19	na	1,2	1,3,12	prob	x	x	x	x	x	x	x
9	5	10	4	2,4,5,6,7	opp/prob	x	x	x	x	x	x	x
10	3	9	1	1,4,10	opp/prob	x	x	x	x	x	x	x
11	9	3	5	5	opp	x	x	x	x	x	x	x
12	17	16	2	2	opp	x	x	x	x	x	x	x
13	11	11	1,3,5	1,3,5	prob	x	x	x	x	x	x	x
14	21	19	2,5	2,5	opp/prob	x	x	x	x	x	x	x
15	3	9	1	1,4,10	opp/prob	x	x	x	x	x	x	x
16	7	8	2,3,6	2,3,6	opp	x	x	x	x	x	x	x
17	13	12	3	1,2,3,8	opp	x	x	x	x	x	x	x
18	10	18	1,3,8	1,3,8	prob	x	x	x	x	x	x	x
19	8	4	3,4,5	3	opp/prob	x	x	x	x	x	x	x
20	2	na	2,4	3,8	opp/prob	x	x	x	x	x	x	x
21	6	2	2,4	1,2	prob	x	x	x	x	x	x	x
22	1	2	1,2	1,2	prob	x	x	x	x	x	x	x

Decision Recogn = Decision Recognition; Solution Regn = Solution Recognition;

Auth. of Study = Authorization of further study; Just. = Justification; Auth. = Authorization; Imp. = Implementation.

partners whereas in large firms, various levels of management are involved. A typical procedure begins with the preparation of an investment proposal and requires detailed evaluation and approval by top management.

Stimulus

A decision process begins with the recognition of a need. This is stimulated either by the internal or external factors (including government and suppliers) or both. Section 8 has provided a detailed list of these factors. Since different firms are stimulated by different factors, a list of factors for each case is presented in Table 8.3. Numbers correspond to the numbers in Table 8.1 and Table 8.2.

Decisions can then be classified by the stimuli that evoked them along a continuum of opportunity, problem, and crisis. At one extreme are opportunity decisions, those initiated on a purely voluntary basis, to improve an already secure situation, such as entering into a new market or producing a wider variety of goods. At the other extreme are crisis decisions, those initiated to respond to intense pressures and must be dealt with immediately. Falling in between these two extremes are problem decisions. These are initiated by milder pressures than crisis and do not require immediate attention. However, delaying attention on the problem situation will turn them into crisis situation.

The 22 samples can be categorized as follows: 0 crisis decision, 6 opportunity decision, 9 problem decisions, and 7 opportunity-problem decisions. The absence of crisis decision is due to the inherent characteristics of AMTs. The adoption of AMTs requires a long period of planning and the feedback is not immediate. Also, AMTs allow users to improve the current situation by producing more quantity and variety of goods and saving costs. Thus, AMTs are only recognized as solutions in opportunity and problem situations but not in crisis situations.

Solution Identification Stage

The solution identification stage comprises three routines in the framework of this study: recognition of decision, in which managers recognize opportunities, problems, and crises and evoke decisional activity, diagnosis, in which managers seek to find a cure for the recognized problem situation, and solution recognition, in which AMTs are identified as the solutions.

When the internal and external stimulus reach a threshold level, the decisional activity is evoked. It can start anywhere in the organization. In the sample, half of the cases started from the top (top-down) where the top management received the stimulus. The other half started from the bottom where the production and engineering staff recognize the need to improve their productivity or save labour costs.

After the decisional activity is evoked, most of the firms can immediately identify the solutions without going through the diagnosis routine. However, in two cases, consultants are called in to search for a solution where AMTs are subsequently identified as solutions.

Different from Mintzberg, Raisinghani, and Theoret's and Nutt's findings where the solution is recognized in later part of the decision process, all but the above two sample firms are able to identify AMTs as their solutions at the beginning of the decision process. Careful analysis of the interview results reveals that in the opportunity situation, solution seeks for problem not vice versa. For instance, an owner of a small manufacturing firm was exposed to CAD/CAM and decided to use CAD/CAM to create a new product line that he has never thought of before. In the problem situation, the decision makers realize that some problems have been experienced by other companies and AMTs seemed to be good solutions for them. For example, a manufacturer engaged in custom metal fabricating has suffered from

increasing cost of labour. After hearing about a successful robot installation from a friend in the same business, the owner decided to acquire the same robot for a spot welding operation.

Detailing

The detailing stage involves preliminary authorization, in which upper level approval for further development of the solution is sought, and search, in which potential suppliers of suitable systems are identified.

In the preliminary authorization routine, the decision making group delegates the investigation of the possibility of adopting AMTs to a task force. It is usually composed of industrial engineers and, in some cases, accountants and ultimate users of the system. The task force is responsible for refining the needs of the firm, searching for potential suppliers, screening and evaluating each potential system. At the end, a report (either orally, written or in the form of a presentation) is presented to the decision making group. For example, a diversified electrical equipment manufacturer requested for a feasibility study on the possibility of acquiring robotic welding systems. The study was done by a committee headed by the Technical Services Department with a mandate to increase the productivity by using robots. The study identified the most suitable machine and outlined the quantitative and qualitative savings.

The search routine is of five types: passive, organizational, professional, trap, and active. Passive search is the waiting for unsolicited suppliers to appear. Organizational search involves the use of past experience to identify a suitable supplier. This is commonly used by firms that have invested in AMTs before. Professional search is the gathering of information by hiring consultants, attending conferences, trade shows, or reading professional magazines. Trap search is to let

potential suppliers know that the firm is looking for certain equipment. This can be achieved by requesting for proposal or directly calling suppliers for information on their equipment. Active search means the direct seeking of certain equipment by site visit of suppliers or users of that type of equipment until a suitable system is found. The main difference between trap and active search is that the former is done at a point in time such as selecting the best proposal out of those submitted whereas the latter is longitudinal search until suitable equipment is found.

TABLE 8.4 FIVE DIFFERENT SEARCH TECHNIQUES

Firm	Search Techniques:				
	Passive	Organizational	Professional	Trap	Active
1			x		x
3			x		x
7			x		x
9			x		x
11		x		x	
15		x		x	
21		x		x	
22		x		x	
2			x	x	
10			x	x	
13		x			
20		x			
4	x		x		
6					x
14	x				
18				x	

Table 8.4 lists 16 of the 22 decisions that are using the search routine. Many decisions use a combination of these five search techniques. Using information from professional magazines (professional search) and then directly visiting suppliers or users of certain equipment (active search) appear to be a very common technique. The use of organization's past experience to identify possible suppliers (organizational search), and then send out request for proposal (trap search) is also very common.

Evaluation Stage

The evaluation stage is crucial since results of the evaluation directly determine whether the investment proposal will be accepted or not. Two routines in this stage are screening and justification. The screening routine is evoked to narrow down the alternatives to one when search has generated more than one alternative. The justification routine is used to evaluate intensively the chosen equipment to see whether it is financially and/or strategically justified.

In the screening routine, firms either use an objective weighted scoring methods or a subjective judgment method. The former involve the setting up of criteria for choice, assigning weight to each criteria, and then giving points to each of the alternative equipment. The equipment that scored the highest points is chosen. The subjective judgment method represents the use of qualitative judgment to select the best out of a few alternatives presented. For instance, a communication equipment manufacturer identified three potential systems and one is selected after a presentation made by systems engineers who compared and contrasted various aspects of these three equipment. In the 22 decision processes, screening routine is noted in 11 cases: 3 in scoring and 8 in judgment.

In the justification routine, quantitative and qualitative methods are used. The quantitative method involves the use of ROI, payback period and discounted cash flow methods to measure cost savings or increase in profits. By far, justification of the AMTs by labour cost savings through the use of payback period is most common. The qualitative method involves the assessment of the strategical need of the company and the improvement of quality and competitiveness of the product produced using AMTs. Both methods can be used at the same time. In the 22 decisions, 20 use the justification routine: 3 use only quantitative, 6 use only qualitative, and 11 use both.

In these 20 cases, although some may use both methods, the ultimate decision is based heavily on one of the two methods. For instance, a manufacturer engaged in sheet metal fabrication, due to capital constraint, has a very strict rule that investments with a higher than 2-year payback will not be accepted; whereas a large automobile manufacturer states that a longer payback period can be accepted if the investment can improve product quality. A quantitative method is dominant in the former and qualitative in the latter.

A somewhat astonishing result is found when the author explored the relationship between the size of the firm, as measured by the number of employees, and the dominance of the techniques. The 8 largest firms, of which the largest 7 use both methods, are dominated by the qualitative methods so is the 5 smallest firms, of which the smallest 4 firms do not use quantitative methods. The 7 firms in between these two groups are dominated by quantitative method.

The possible explanations for this phenomenon is that the largest firms recognize the strategic importance of AMTs. Although quantitative methods are used in order to provide comparisons among various investment proposals, the final decision is based on the strategical need of the company. The smallest companies, most of whom are owner/manager type, where the initiator is the decision maker, do not have the resources and knowledge to perform detailed quantitative analysis. Thus, investment decisions are made based on their judgment. The medium size companies have several layers of management and the report is prepared and evaluated by top management. A strict quantitative guideline is set so as to ensure that capital investments yield the highest possible return.

Authorization Stage

The final stage before the AMTs are implemented (or rejected) is the

authorization stage. Seventeen of 22 decisions have evoked this routine. The other 5 decisions are made without this routine since they are the owner/manager type where the initiator is the decision maker. For most of the 17 cases, the decision has to be approved by the top management since AMTs require the commitment of large amounts of corporate time and resource.

Having identified the five stages of the AMT decision process, elements of the AMT decision process can then be analyzed in order to detect any common patterns of these decision process. Based on the results of Table 8.3, a general model of the AMT decision process is derived and explained in detail in the following section.

8.3 A general model of the AMT decision process

The elements of the AMT decision process can now be brought to a common base. A general model of the process is developed and shown in Figure 8.2. The model is composed of nine basic routines, from decision recognition to implementation, as well as the factors impacting AMT investment decision. The model can be used to illustrate the structure of each of the 22 decision processes.

The arrows represent the direction of the decision process and the circles represent the branching out of the direction. For example, after the decision recognition routine, some decision processes move to diagnosis routine and others move on to other routines without evoking the diagnosis routine. The decision process is evoked once the external and internal factors reach a threshold level and ended with implementation. Suppliers and governments exert influence in all the routines of the decision process.

The main horizontal line of the model shows the two basic routines, the decision recognition and implementation routines. Of these 22 decision processes, no decision process has only these two routines. The routine that each decision making

FIGURE 8.2: A GENERAL MODEL OF THE AMT DECISION PROCESS

process has gone through is depicted in Table 8.5. Careful analysis of each of these decision process leads to the development of five different specific models that can be used to describe the 22 decision processes.

TABLE 8.5 FIVE TYPES OF AMT.DECISION PROCESSES

	<u>Solution Identification</u>		<u>Detailing</u>		<u>Evaluation</u>		<u>Auth.</u>	<u>Imp.</u>
	<u>Decision Diag-</u>	<u>Solution</u>	<u>Prelim.</u>		<u>Screen-</u>			
<u>Firm</u>	<u>Reg'n</u>	<u>Reg'n</u>	<u>Auth</u>	<u>Search</u>	<u>ing</u>	<u>Just.</u>		
1. Contingency Model								
12	x						x	x
16	x						x	x
2. Owner/Manager Model								
1	x	x		x		x		x
4	x	x		x		x		x
7	x	x		x		x		x
9	x	x		x		x		x
14	x	x		x		x		x
3. Experienced Model								
8	x	x				x	x	x
19	x	x				x	x	x
4. Turnkey Model								
5	x	x				x	x	x
17	x	x				x	x	x
5. Structural Analysis Model								
2	x	x	x	x	x	x	x	x
3	x	x	x	x	x	x	x	x
6	x	x	x	x	x	x	x	x
10	x	x	x	x	x	x	x	x
11	x	x	x	x	x	x	x	x
13	x	x	x	x	x	x	x	x
15	x	x	x	x	x	x	x	x
18	x	x	x	x	x	x	x	x
20	x	x	x	x	x	x	x	x
21	x	x	x	x	x	x	x	x
22	x	x	x	x	x	x	x	x

Decision Reg'n = Decision Recognition; Solution Reg'n = Decision Recognition;
 Prelim. Auth. = Authorization of preliminary study; Just. = Justification;
 Auth. = Authorization; Imp. = Implementation.

believed that most of the causes of the problem of slow AMT adoption have been identified. In fact, the inability of capital budgeting techniques to incorporate the intangible factors in the evaluation process is believed to be the major barrier. Having passed this problem discovery stage, researchers have been trying to identify the intangibles. Flexibility and strategic factors are identified as the most important intangibles that are missed out in the evaluation. Considerable amount of work has been concentrated on the measurement of these factors. Scoring model, sensitivity analysis, and lowering of hurdle rates are methods suggested in this measurement stage. The practicality of these models have not been proven. On the contrary, the problem of slow adoption continues. There seems to be a gap between the missing factor identification stage and the measurement stage.

This may suggest that we do not have a clear understanding of the underlying causes of the slow adoption problem. Although the inability to incorporate flexibility and strategic factors, and other reasons that have been mentioned, have been identified as the major causes, careful examination of how managers made AMT decisions need to be explored to provide more insights into the slow adoption problem.

Survey of AMT Adoptions

By analyzing organizations that have installed AMTs, through an examination of various information sources, some patterns and trends of AMT adoption in Canada are uncovered. First, years of adoption, applications, and locations of these AMTs are found and presented in summary forms. Second, AMTs that are used in manufacturing industries are analyzed in detail by comparing the specific attributes of these firms. These attributes include sectors of the economy, sizes of the firms, and ownership structures. Finally, patterns and trends of the Canadian AMT adoption are compared with those of the other industrialized nations to see whether Canada is lagging behind or

8.4 Five types of AMT decision making models

The 22 decision processes could be represented in terms of the basic model. Also, the 22 decision processes fall into 5 groups: each group begins with decision recognition routine and ends with implementation routine, the distinction of each model proved to be the intermediate routines between these two basic routines. These models can be called the contingency, owner/manager, experienced, turnkey, and structural analysis models. Brief descriptions of these are provided in the previous section and detailed analysis and discussions of them are presented below.

Contingency Model

The contingency model activates the decision recognition, authorization, and implementation routines. This is shown in Figure 8.3. The simplicity of this model is due to the fact that the AMT decision process is only a subcomponent of a larger decision process. In one case, a shopping cart manufacturer engaged in a joint venture with a foreign firm. The foreign firm installed a completely new manufacturing process for the domestic firm where robots were just part of the whole manufacturing process and the robots were installed without any evaluation or authorization. The only authorization needed was the approval by top management to allow the installation of the new manufacturing process.

The major characteristics of this model are the presence of a larger investment in which AMTs are just a subset of it and the firm's total trust on the project development group. These characteristics have allowed the decision process to be a very simple one and to skip the diagnosis and solution recognition routine as well as the detailing and evaluation stages.

Owner/Manager Model

The owner/manager model activates the routines of solution recognition,

FIGURE 8.3: CONTINGENCY MODEL

search, and justification, in addition to the two basic routines. This is shown in Figure 8.4. The decision process is usually evoked by a combination of personal desire and company's growth opportunity. In the 5 cases, 3 decision makers (owner/managers) recognized AMTs ability to help their company grow. The other 2 cases are based on personal desires. Decision makers of these 2 firms have been able to fit their personal desires into their business plans.

Once AMTs are identified, two techniques are common. First, based on the knowledge from professional magazines, and trade shows (professional search), the decision makers directly called up one supplier and asked for quotation (active search). The decision makers do not contact other suppliers because they do not have enough time and resource to evaluate other alternative suppliers (i.e. no screening routine). Usually, the supplier is selected either by their reputation, performance demonstrated in the trade show, or recommendation from business acquaintance.

The second searching technique begins with gaining knowledge through attending trade shows and reading magazines (professional search). Decision makers are not motivated to evoke a decision process until some unsolicited salesman of the AMT suppliers came and presented a system (passive search).

Based on one of these two techniques, the justification routine is evoked. The analysis strictly based on mental feeling of the strategical need of the firm which is heavily influenced by the decision maker's personal desire. The evaluation was not based on the labour savings; rather, it was based on whether the increase in sales generated by the machine can cover the cost of the machine. The evaluation was done mentally and no quantitative method was used. All these firms voiced the same concern that AMTs are too new to provide reliable data for estimating cost savings. Also, the nature of their business is highly competitive and the future is so uncertain that any

FIGURE 8.4: OWNER/MANAGER MODEL

quantitative evaluation using hard figures is useless.

There are several major distinctions between this model and the others. First, the two authorization routines are not evoked. It is because the decision maker is the sole owner who has the capacity to make all business decisions. Second, all the decision makers in these firms are technically-trained and have been keeping abreast with current technology. They know what is available for them. In addition, most of these decisions are opportunity type where the solution seeks for problem; thus, the diagnosis routine is not evoked. Third, as mentioned before, the screening routine is not activated since the decision maker does not have enough time and resources to evaluate different alternatives. Once they found a suitable one, they will commit to that instead of searching for the best available system.

Experienced Model

The experienced model activates solution recognition, justification, authorization and the two basic routines. As the name implies, firms in this model have already had the experience of acquiring AMTs. Two decision processes can be classified in this category.

In both cases, the diagnosis routine, the whole detailing stage, and the screening routine were skipped since the firms knew what they wanted and who could provide the type of equipment they needed. Thus, once the need was identified, the firm could identify the solution very quickly. When the solution had been identified, quantitative analysis was performed. Since the data on incremental cash flows was readily available from the experience gained from the previous investments in AMT, the firm could easily estimate the cost savings or revenue increases. The annual incremental cash flows then could be used to compute the ROI and payback period. A capital appropriation form or a summary report was prepared by the originator. In the

FIGURE 8.5: EXPERIENCED MODEL

form, or the report, incremental savings, ROI, and payback period were clearly indicated and supported with hard figures; thus, approval was granted quite easily. Consequently, no qualitative analysis was needed. This model is shown in Figure 8.5.

For example, the auto parts supplier has just received a large contract and there was a need to increase the flexibility of production volume. Once this need was identified, the firm quickly determined that an additional robot of the same type as the previous one should be acquired. Quantitative analysis was done based on the data from the timing study of the previous machine to generate labour cost savings, expected sales value of the parts produced by the machine etc. These are used to compute ROI and payback period. The firm has found that the contract sales volume was enough to justify the investment in the additional robot; thus, the investment was easily approved.

In short, the experience gained from previous investment in AMTs has made the decision process of these firms different from firms in other models. The experience helped to provide hard figures for justification and thus expedited the decision process significantly.

Turnkey Model

In terms of decision making routines, the turnkey model is very similar to the contingency model except that the former has the diagnosis routine. However, these two models are very different in substance. Firms in the turnkey model either do not have the expertise, knowledge, and resources to solve an organizational problem or do not realize some good opportunities. Consequently, consultants are hired to diagnose or suggest ways to tackle present problems or to improve an already secured situation. The consultants are commissioned to find out present problems or opportunities and to provide recommendations. Based on the consultant's report, the firm then perform analysis. The solution recognition routine, detailing stage and screening routine are

FIGURE 8.6: TURNKEY MODEL

missed since these tasks are done by the consultants. This is shown in Figure 8.6.

A consultant report is generated at the end of the process. A typical consultant report includes recommendations such as which system to buy, how to implement, and the potential cost savings. Based on these results, the firms can then evaluate (justification routine) the desirability of the AMT investment. Both qualitative and quantitative analyses can be used. In one case, a manufacturer of braking systems found that quantitative savings suggested by the consulting firm was enough to justify the system (the payback rule for the firm is 2 years and the investment has a 4.7 months payback period); therefore, no further qualitative evaluation was needed.

In sum, this model is different from others since the firms are not able to recognize AMTs as their solutions to the problems; thus, consultants had to be hired to identify the problem or opportunity.

Structural Analysis Model

The structural analysis model is shown in Figure 8.7. It evokes all the routines except the diagnosis routine. The diagnosis routine is not evoked in this model for two reasons. First, in the opportunity situation where solution seeks for problem, no problem is to be diagnosed. Second, in the problem situation, the decision makers tend to recognize AMTs as their solutions fairly quickly. It is because AMTs have been well publicized in the professional journals and trade shows. Thus, a "bandwagon effect" has been created in which the decision maker thinks that AMTs are the panacea for all manufacturing problems.

In the sample, 11 of the 22 decision processes can be classified in this category. The large number of the samples in this category reflects that firms tend to use this model to make AMT investment decisions. One possible explanation is that AMTs are large investments into something new, i.e. a large risky investment. In order to

ensure that the capital investment is profitable, firms are willing to go through a long and detailed process.

After AMTs are recognized as the solution (solution recognition routine), the preliminary authorization routine, which is only present in this model, is evoked. Since AMT investment is normally a large investment, the preliminary authorization routine ensures that the evaluation process is in detail and thorough by appointing a task force to study the feasibility.

The task force then further refines the need of the firm, i.e. the beginning of the search routine. A number of possible suppliers are identified through various searching techniques. The most common types are the organizational-trap and professional-trap searches: organization's past experience with suppliers who supply them with some similar machines (organizational search) or using information from professional journals and trade shows to identify potential suppliers (professional search), these suppliers are called upon to provide quotes for their equipment or are asked to respond to the firms' request for proposal (trap search).

Once information about the suppliers and their equipment are identified, the screening process is evoked. This routine is not present in other models because only one alternative came up in the other models. It may be due to the lack of importance of the AMT decision (contingency model), the lack of resources to come up and evaluate several alternatives (owner/manager model), the adequacy of past experience to identify a suitable supplier (experienced model), or the use of consultant services (turnkey model). However, in this structural analysis model, usually 3 to 5 alternatives are generated through the search routine. The firms, however, do not have enough financial resources or time to perform detailed quantitative and qualitative analysis on each alternative. As a result, the screening routine is used to narrow the

FIGURE 8.7: STRUCTURAL ANALYSIS MODEL

alternatives to one. This is accomplished by using scoring or judgment methods. The former is a more intense method and requires both technical and financial knowledge in setting up criteria and assigning scores to each alternative. Information and time required for this method is also extensive. Thus, only 3 firms use this method. The rest 7 firms use the judgment method.

When one alternative is selected, it is evaluated extensively either by the quantitative or qualitative method or both. Seven out of 11 cases go through quantitative analysis and then the qualitative analysis. In the quantitative analysis, the AMTs are often measured by the payback period and ROI. Those investments that can pass the quantitative guideline set by the firms are approved quite easily. However, if the investments cannot pass the quantitative guidelines, the AMTs have to be justified by their ability to improve quality, flexibility, and competitive edge etc. It is found that for these 7 firms, qualitative analysis took dominance over quantitative analysis.

For instance, a computer communication system manufacturer has identified the need to acquire a new CAD system to speed up the design process. A task force composed of several engineers and an accountant were formed and three systems were subsequently identified. In a presentation, these systems were compared and one was chosen by the management for further investigation. This system turned out to have a lower payback than the guideline set by the company. However, top management decided to acquire the system based on the fact that the system can speed up the design process which gives the company better response to the market.

For the other 4 firms, 3 went through qualitative justification only. In these 3 cases, the payback rule was used and was very strict: no investment with larger than a specified payback period would be accepted. This implies that qualitative factors were neglected. Finally, there is one case in which only the qualitative analysis is employed.

8.5 Discussions

As mentioned, the AMT decision making process is composed of several stages. However, AMT research efforts have been concentrating on the evaluation stage only and underestimating the importance of the contribution of other stages in the whole decision making process. It would be inappropriate to make suggestions or to build evaluation models without a good understanding of the entire AMT decision making process. The examination of the complete decision making process in this study is designed to throw some light into the need of widening the scope of current research. Also, this study investigates the validity of some criticisms on decision makers' evaluation methods.

Criticisms on the industry's AMT evaluation process can easily be found in the current literature. Examples include Canada(1986), Hodder and Riggs(1986), Goldhar and Jelinek (1986), Nelson (1986), and Emerson(1986). They viewed that many firms have tended to base their investment decisions on traditional DCF financial justification methodologies that are better suited to meeting profitability criteria than to evaluating ways of reaching long-term strategic goals. High hurdle rate, short evaluation horizon, short payback period, and inability to incorporate qualitative factors of AMTs are the problems that they perceived.

As a result, many different methods have been suggested to overcome the inability of the traditional methods. Falter and Choobineh(1986) presented a case study where they analyzed an existing electronics production assembly system under consideration for CAM application. They found that the combination of economic (quantitative) and strategic (qualitative) analysis, the firm has been able to make proper decisions on AMT investment.

Kaplan suggested a similar way to combine difficult-to-measure benefits with

those more easily quantified. He proposed that DCF should be used without accounting for the value of intangible benefits. If at this point a DCF analysis shows a positive net present value, the investment will be taken. If it is negative, it will become necessary to estimate how much the annual cash flows must increase before the investment has a positive net present value. The management then has to decide whether it expects the qualitative factors to be worth at least the amount to turn the net present value from negative to zero. In other words, he suggested rather than attempting to put a dollar tag on benefits that by their nature are difficult to quantify, managers should reverse the process and estimate first how large these benefits must be in order to justify the proposed investment.

Klahorst(1986), on the other hand, insisted that if the cost savings of AMTs are properly measured, traditional financial justification can provide fair result.

The study of the AMT decision process in this section provides a better understanding of the validity of the above criticisms and the usefulness of the above recommendations in the Canadian setting. Most of this literature has neglected the size and complexity of the firms in the decision process. Kaplan's evaluation method works only if the firms have enough resources to do that kind of analysis. In the sample, firms in the owner/manager model do not have the resources to commit to such analysis. Thus, management intuition is used. Researchers should look at the limitation of these firms and develop some workable solutions to help them properly evaluate the AMT investments.

The criticism of high hurdle rates is only partially supported. In the 22 decision processes, DCF analysis is only found in 8 cases, of which only 3 cases have a strict hurdle rate. In 2 cases, the hurdle rates are 25% which are much higher than the firms' cost of capital. In the other case, a large electrical appliance manufacturer

has recognized this flaw and the discount rate used is the inflation rate plus a risk premium which is zero for the AMT investment. For the other 5 cases, DCF analysis only assumed a very minor role in the decision process. However, for the other 15 cases, DCF analysis is not used and, thus, the criticism of a high hurdle rate is not valid.

The results of this study provide partial support to the researchers' criticism of the short evaluation horizon. Many of them complained that AMT investment generate a lot of economic benefits to the firms in an extended period of time; therefore, the use of short evaluation horizon undermines the value of AMTs. In the sample, where evaluation horizon is used, 4 use 10-year horizon and 5 use 5-year horizon or less.

The criticism of short payback periods is found to be valid. The use of payback period is very common among the firms. Most of the firms have set 2 to 3-year payback periods. This short payback rule is resulted from capital constraint, the concern over product and equipment obsolescences. Firms felt that they had many investment opportunities for their limited capital. To achieve the highest return from the capital, only projects with very short payback periods are taken. Also, the shortening of product life cycle has made firms' investment in capital equipment very vulnerable. To avoid the risk of equipment obsolescence, a short payback period is used. Consequently, only capital equipment that has immediate feedback will be invested; equipment that has long term benefits are always ignored. This has led to the decline of long term competitiveness of the Canadian manufacturing industries.

Fortunately, the recommendations by Kaplan and Nelson are actually in use by some of the firms. Seven out of the 11 firms in the structural analysis model have first performed the quantitative analysis (though most of them use payback instead of DCF analysis) and then the decision making group looked at the qualitative values of the

investment before the decision was made. Firms in the turnkey model are the same except that the background information for evaluation is provided by the consultants. Most of the firms in these two models expressed that qualitative analysis is only performed when the AMT investment has a longer payback period. This is consistent with Kaplan's recommendation. The other 3 firms, however, use only quantitative or qualitative analysis but not both. Thus, it can be seen that Canadian manufacturers are actually using what the literature has proposed. The only improvement will be the use of DCF analysis instead of payback periods which does not consider the time value of money and ignores distant cash flows.

Nelson's scoring method is used to choose the best alternative out of the several alternatives. However, most firms in the structural analysis model do not have enough resources and time to calculate net present value or incremental savings of each alternative. Thus, more general criteria are used to select one alternative and then perform the quantitative and qualitative analysis on the chosen alternative. Theoretically, Nelson's method is superior than the methods used by firms in the structural analysis model. However, practically, taking into consideration of time and resources, the method used by managers is better than what Nelson has suggested.

For firms in the experienced model, the Klahorst's approach is used. It is because those firms have prior experience in AMTs and they can estimate the savings precisely. However, firms in the other two models do not use any of the recommendations by the researchers. As explained before, the owner/manager type lacks the skill and resources whereas the contingency type does not treat AMT decision as an important decision.

In sum, in order to develop better evaluation models for the industry, one should consider the needs of the firms and the availability of corporate resources to be

devoted to the decision process. Also, the availability of information for their evaluation and the efforts needed to obtain this information has direct influence on the ways the firms make their decisions. The size and the structure of the firms have to be taken into consideration, that is models that are suitable for large firms may not be suitable for small firms

9. INVESTIGATION OF THE RESEARCH ASSUMPTIONS

Having discussed the decision making process used in the adoption of AMTs, this section concentrates on the evaluation stage of the process. In Section 5, four research assumptions often cited in literature of AMT investment decisions are extracted. These assumptions are: overemphasis on labour cost savings, underestimation of the importance of flexibility, status quo assumption, and the inadequacy of the capital budgeting techniques. Each of these research assumptions is examined separately through the aid of the research question and hypothesis derived in Section 5.

9.1 Labour cost savings assumption

Most researchers hold the view that labour cost savings are treated as the most influential factor in evaluating AMTs. As Goldhar²³ puts it "the problem with our traditional approach to capital budgeting is that we look at a new machine in terms of 'first order' effects -- that is, in terms of labour replacement ... we don't think about 'second order' effects like improved quality, faster turnaround time for quicker response to the market place..." This view is echoed by Hill(1986), Kaplan(1986), Van Blois(1983), Barrie(1985), Craig and Noori(1986a,b) and many others.

To see whether this view is still true, the following research question needs to be answered: *"Are labour cost savings the most important consideration in justifying AMT investment?"* The answer to this question would be "yes" if one finds that the majority of the firms considers labour cost savings the most influential consideration. Also, it is interesting to find out whether other labour-related factors are considered most influential by the majority of the firms. Therefore, the following null hypothesis needs to be examined:

More than 1% of the firms consider labour-related factors most influential considerations in AMT investment

If the null hypothesis with $t \geq 50\%$ is not rejected, one can conclude that labour-related factors are still the most influential factors; otherwise, if the null hypothesis is rejected, the views held by the researchers should be seriously questioned. Also, correlation analysis is used to uncover any possible relationships between firm specific attributes and the importance of the labour-related factors.

Summary Statistics

Table 9.1 summarizes the results of the quantitative part of the questionnaire in page 4 of Appendix 5 concerning labour-related factors. On a scale of not influential at all(1) to most influential (5) , the average score and the standard deviation for each labour-related factor are shown. Separate results for the 10 CAD/CAM firms and the 10 robot firms are displayed as well. Among all the labour-related factors, only "increasing cost of labour"(L1) and "reduction of labour cost"(L7) have average scores higher than 3 in the aggregate sample. This indicates that on average only these two factors are considered influential; others are not influential.

When the CAD/CAM firms and robot firms are investigated separately, a different picture is found. "Reduction of labour cost"(L7) is still an influential factor in both cases; however, "increasing cost of labour"(L1) is only influential in the CAD/CAM subsample and "the lack of skilled labour"(L3) becomes an influential factor in the CAD/CAM subsample.

The summary statistics presented in Table 9.1 show an interesting phenomenon. There are major differences between CAD/CAM and the robot subsample. The differences suggest that firms investing in robots are doing so mainly for labour replacement (cost reduction) whereas firms investing in CAD/CAM are trying to avoid

the hiring of skilled labour and to improve the efficiency of current labour. This last point is supported by the finding that there is a lack of skilled labour in the CAD/CAM subsample.

TABLE 9.1: AVERAGE SCORE (STANDARD DEVIATION) OF LABOUR-RELATED FACTORS

	<u>L1*</u>	<u>L2</u>	<u>L3</u>	<u>L4</u>	<u>L5</u>	<u>L6</u>	<u>L7</u>
<u>TOTAL**</u>	3.14 (1.32)	2.27 (1.20)	2.73 (1.41)	1.77 (1.15)	2.36 (1.29)	2.77 (1.38)	3.64 (1.43)
<u>CAD/CAM</u>	3.20 (1.03)	2.30 (1.42)	3.30 (1.49)	1.50 (0.85)	2.00 (1.25)	2.30 (1.34)	3.10 (1.52)
<u>ROBOT</u>	2.80 (1.55)	2.10 (1.10)	2.00 (1.33)	1.80 (1.40)	2.60 (1.43)	3.00 (1.41)	4.00 (1.33)

*corresponding to the factor in the questionnaire. For example, L1 is "increasing cost of labour"

**Includes two FMS firms.

Also, the summary statistics give partial support to the researchers' view that labour cost savings are influential in AMT decisions. To determine whether the majority of the firms considers them most influential, statistical tests are performed and shown below.

Testing of Hypothesis

Following the methodology described in Section 6.3.1, the above null hypothesis is tested for each of the labour-related factors. The cumulative binomial probability, $P(X \geq X_i | n, p)$, for each $X \geq X_i$ (where $i = 0, 1, 2, \dots, 22$) is computed. The proportion, p , is computed by dividing the number of firms reporting that labour-related factors are most influential (Table A8.1 of Appendix 8) by the sample size, n (22 in the aggregate sample and 10 in the robot and CAD/CAM subsamples). For example, as shown in Table A8.2 of Appendix 8, the probability of 5 or more firms considering "increasing cost of labour" most influential is 4.41%. In other words, in

repeated sampling of the same population with the same sample size, 4.41% (i.e. $\alpha = 0.041$) of the time, 5 or more firms will consider "increasing cost of labour" most influential. A detailed list of all the cumulative binomial probabilities (i.e. $X \geq X_i$ where $i = 0, 1, 2, \dots, 22$) for each labour-related factor is provided in Table A8.2 of Appendix 8. Similar statistics for the CAD/CAM and the robot subsample are shown in Table A8.3 and Table A8.4 in Appendix 8 respectively. The summary statistics of Appendix 8 are presented in Table 9.2 below.

Table 9.2 summarizes, with 95%, 90%, and 80% confidences (i.e. $\alpha = .05, .10, \text{ and } .20$), that X_i firms in the population consider labour-related factors most influential factors. The numbers in brackets represent the percentage of firms of the corresponding numbers. For example, for factor L1, the upper limit for $\alpha = 0.05$ is 4 firms which is equal to 18% of the 22 firms. Thus, the number in the bracket is 0.18. In the sample, 50% or more of the firms (i.e. $t\% \geq 50\%$), with 5% probability, consider "reduction of labour cost" (L7) most influential factor. Thus, the null hypothesis that more than 50% of the firms consider this factor most influential cannot be rejected. However, the null hypothesis that more than 55% of the firms consider the factor most influential can be rejected. This implies that 5% of the time, in repeated sampling, slightly more than 50% (11 firms) but less than 55% (12 firms) of the firms consider the factor most influential. For the rest of the factors, the null hypothesis for more than 50% ($t \geq 50\%$) of the firms can be rejected. This implies that majority of firms does not consider any of the labour-related factors except "reduction of labour cost" most influential. This is the only factor that, more than 5% of the time, resulted in slightly more than half of the firms in the population consider it most influential.

However, when the sample is divided into CAD/CAM and robot subsamples, the

results are different. Five percent of the time, 40% or more ($\geq 40\%$) of the CAD/CAM firms in the population considered "lack of skilled labour" most influential. Thus, the null hypothesis that 40% or more of the CAD/CAM firms consider this factor most influential cannot be rejected. The null hypothesis for the other factors can be rejected for a very low t value. As a result, it can be concluded that there is not sufficient evidence to indicate that a majority of firms considers any of the labour-related factor most influential in the CAD/CAM subsample.

TABLE 9.2: SUMMARY OF THE UPPER LIMITS OF NUMBER OF FIRMS IN THE BINOMIAL PROBABILITY TEST OF LABOUR-RELATED FACTORS*

	L1	L2	L3	L4	L5	L6	L7
TOTAL(N=22)**							
$\alpha = 0.05$	4(0.18)	0(0.00)	6(0.27)	3(0.14)	0(0.00)	3(0.14)	11(0.50)
$\alpha = 0.10$	4(0.18)	0(0.00)	5(0.23)	2(0.09)	0(0.00)	2(0.09)	10(0.45)
$\alpha = 0.20$	3(0.14)	0(0.00)	5(0.23)	2(0.09)	0(0.00)	2(0.09)	9(0.41)
CAD/CAM(N=10)							
$\alpha = 0.05$	0***	0	4	0	0	0	3
$\alpha = 0.10$	0	0	4	0	0	0	2
$\alpha = 0.20$	0	0	3	0	0	0	2
ROBOT(N=10)							
$\alpha = 0.05$	3	0	3	3	0	3	8
$\alpha = 0.10$	2	0	2	2	0	2	7
$\alpha = 0.20$	2	0	2	2	0	2	6

* Number in each cell indicates the upper limit of the number of firms that the null hypothesis, of considering labour-related factors most influential, cannot be rejected.

**includes two FMS firms.

*** % of firms are not given since it is just the number divided by ten.

For the robot subsample, the null hypothesis that 80% or more ($\geq 80\%$) of the firms consider "reduction of labour cost" most influential factor cannot be rejected. However, for the rest six factors, the null hypothesis of 50% or more of the robot firms consider these factors most influential are rejected. Therefore, it can be concluded that, except for the reduction of labour cost factor, the majority of firms does not consider labour-related factors most influential in the robot subsample.

In short, the null hypothesis that a majority of firms considers labour-related factors most influential factors in the aggregate sample can be rejected with 90% and 80% confidence level. However, "reduction of labour cost" is the only factor which cannot be rejected in the 5% level (i.e. 95% confidence level). In the CAD/CAM subsample, the null hypothesis can be rejected for all α values. In the robot subsample, the null hypothesis for the "reduction of labour cost" factor cannot be rejected. Other factors, however, can be easily rejected.

In order to explore whether there is any relationship between the importance of labour-related factors and the firm specific attributes, correlation analysis is used. The three attributes investigated are number of employees, annual sales, and the cost of investment.

Number of employees and sales measure the size of the company. One may suspect that the larger the company, the more knowledge they will have in the area of manufacturing technology. Therefore, they will not focus narrowly on the labour saving function of AMTs. On the other hand, one may argue that the higher the number of employees, the higher the labour costs and the more likely that the firm will try to reduce those labour costs. Thus, labour-related factors are very important.

The cost of investment measures the importance of the investment. The larger the size of the investment, the more important it is for the firm to properly evaluate the investment. Therefore, one may suspect that firms will spend more effort to find out the real benefits of AMTs if they are expensive and will not be too narrowly concentrated on the labour saving function. On the other hand, one can argue that firms tend to be very cautious in investing large sums of money. Thus, justification based on hard data (labour costs) is preferred to justification by strategic reasons that are not measurable.

To find out the possible relationships, Table 9.3 summarizes the correlation between the percentage contribution of labour-related factors and each of the three firm specific attributes. As can be seen, correlations between labour-related factors and each of the three attributes are very low. When these correlations are tested one by one using the null hypothesis that there is no correlation between labour factors and the particular attribute with the statistic²⁴: $t^* = r(n-2)^{.5} / (1-r^2)^{.5}$, the null hypothesis cannot be rejected in all of the three cases. This also holds true for the CAD/CAM and the robot subsamples. The results suggest that, 1) there is no relationship between the importance of labour-related factors and size, and 2) cost of investment cannot be used to explain the importance of labour-related factors in AMT decisions.

To explore the importance of labour-related factors relative to the flexibility-related factors, a paired-sample t-test is applied to the quantitative data obtained from the questionnaire on page 5 of Appendix 5 which asked the respondents to give a percentage contribution of labour-related, flexibility-related, and other factors in the AMT decision. The null hypothesis is that there is no difference in ratings between these 2 groups:

$$H_0: \mu_d = 0 \text{ where } \mu_d = \mu_{lab} - \mu_{flex} \quad \text{where } \mu \text{ is the average \% contribution; and} \\ \text{subscripts "lab" and "flex" represent} \\ \text{labour-related factors and flexibility-related} \\ \text{factors respectively.}$$

TABLE 9.3: CORRELATION RESULTS OF LABOUR-RELATED FACTORS

	<u>Aggregate Sample *</u>	<u>CAD/CAM Subsample</u>	<u>Robot Subsample</u>
Number of Employees	0.028	0.231	-0.119
Annual Sales	0.053	0.197	-0.165
Cost of Investment	0.004	0.334	-0.145

*includes two FMS firms.

As indicated in Table 9.4, the average percentage contribution of the

labour-related factors is 5.91% higher than that of the flexibility-related factors. However, this is not statistically significant due to the high standard deviation.

When the test is applied to the two subsamples, opposite results are found: 1) the CAD/CAM subsample has a low negative mean, indicating that the percentage contribution of flexibility-related factors are slightly higher than that of the labour-related factors; and 2) the robot subsample has a high positive mean, indicating that the percentage contribution of labour-related factors is substantially higher than that of the flexibility-related factors.

TABLE 9.4: PAIRED T-TEST OF LABOUR AND FLEXIBILITY

	<u>N</u>	<u>Mean</u>	<u>St. Dev.</u>	<u>T value</u>	<u>P Value</u>
Total*	22	5.91	46.49	0.60	0.560
CAD/CAM	10	-16.5	33.80	-1.54	0.160
Robot	10	31.0	50.30	1.95	0.083

*includes two FMS firms.

The small difference in the means of the two different factor groups in the CAD/CAM subsample is not statistically significant. Therefore, it can be concluded that equality of means between the labour-related factors and flexibility-related factors cannot be rejected in the total sample and the CAD/CAM subsample.

Although there is a high standard deviation of the paired difference of these two factor groups in the robot subsample, the high difference in the means between these two factor groups has produced a statistically significant result with 90% confidence, that is, the null hypothesis of equality of means is rejected and since the difference is positive, one can further conclude that the labour-related factors are more important than the flexibility-related factors.

Both in the binomial test of proportion and the paired t-test of difference, it can be showed that there is a major difference between the CAD/CAM subsample and the robot subsample. Specifically, labour cost savings are very important in the robot

subsample but not in the CAD/CAM subsample. This is indicated by the inability to reject the null hypothesis that "reduction of labour cost" is a most influential factor in the binomial test of proportion and the labour-related factors are more important than the flexibility-related factors in the paired t-test of difference in the robot subsample. Due to these differences, results of the two subsamples are analyzed separately below.

CAD/CAM Analysis

As noted above, none of the labour-related factors is a most influential in the CAD/CAM subsample. This finding, of course, is in direct contradiction to the literature's position that most firms consider the labour saving functions of CAD/CAM as being most influential in the decision making process. It seems that those who have implemented CAD/CAM successfully have recognized that labour savings are not a most influential factor for acquiring CAD/CAM.

Although statistical tests show that none of the labour-related factors is considered most influential by a majority of firms, careful examination of the summary statistics as well as the raw data shows that "reduction of labour cost" and "lack of skilled labour" have a certain degree of importance in the AMT decision.

Also, it is found that the definition of labour is different between the CAD/CAM and robot subsamples. In both subsamples, interviewees concern the labour that is affected by the introduction of AMTs. This includes the labour being replaced by the AMTs, the additional labour required to operate the new equipment, and the existing labour who will be using the new equipment. In the CAD/CAM subsample, interviewees believe that CAD/CAM does not directly eliminate any workers.

It is found that the investment in CAD/CAM is usually aimed at improving the productivity of current labour and delaying the need to hire additional workers. Also, it replaces the unskilled labour by the skilled labour by a ratio of higher than 1.

"Reduction of labour cost" is thus achieved by: 1) replacing large number of unskilled labour with small number of skilled labour; 2) utilizing existing workers to produce more; and 3) generating output at a faster rate.

"Lack of skilled labour" has some influence in the AMT decision since CAD/CAM can improve the effectiveness of current skilled labour and delay the need to hire more. An executive of a major Canadian weaponry manufacturer pointed out that the real savings are the ability of the engineering staff to perform more tasks in less time and, therefore, delay the need to hire more people. For some smaller firms, the use of CAD/CAM minimizes their reliance on technical personnel.

As many firms have indicated, "reduction of labour cost" and "lack of skilled labour" are just two minor factors. The main reasons for investing in CAD/CAM are to create a new product line, to increase product variety, to improve product quality, and to achieve a faster response rate. These are confirmed by the paired t-test result which shows that flexibility-related factors are more important than labour-related factors, even though it is not statistically significant due to a high standard deviation and small sample size.

The main reasons for investing in CAD/CAM that are mentioned by firms are the actual characteristics of CAD/CAM. This indicates that the decision makers, at least those in the sample, are "smart" enough to recognize the real benefits of CAD/CAM rather than basing their decisions on the labour cost saving function of CAD/CAM. Therefore, the assumption that labour cost savings are most influential considerations in the investment of CAD/CAM can be rejected. In other words, labour cost savings are not the main reasons to invest in CAD/CAM. Given the results of this study, the statements made by the researchers concerning labour savings as most influential factors in investment in CAD/CAM appear to be invalid.

Robot Analysis

In the robot subsample, the statistical test provides support for the "reduction of labour cost" being a most influential factor for the majority of robot firms. All other factors are unsupported; however, examination of the raw data and summary statistics reveal that "increasing cost of labour," "lack of skilled labours," "employees unwilling to perform certain jobs," and "eliminate repetitive job" are also influential even though they are not most influential.

Labour in the robot subsample usually refers to the labour that is replaced by the robot and the additional workers that are required to operate the robot. Since most of the robots in the sample are welders and pick-and-place robots, they simply perform the tasks previously done by manual workers. Therefore, the labour cost saving is simply the operational costs of the robots less the costs of manual labour required to perform the same task, taking into consideration the changes in operating and maintenance costs.

In fact, these kinds of robot are just used as close substitutes for human beings in repetitive and tedious tasks. Since these robots can work continuously, the downtime for tooling and maintainance is minimal and their productivity is much higher than for manual workers who require a lot of breaks due to boredom, high temperature of the environment, heavy weight of the products and personal reasons.

The reduction of labour cost does not come from a cheaper hourly rate for robots. Generally speaking, the cost per hour for a robot is higher than the cost of manual workers needed to perform the job; however, as an engineer of a material handling machinery producer pointed out, the "saving comes from the robot's ability to work continuously and [they] do not have to go to the washroom or talk to their fellow workers."

As many firms that are using robots have strong labour unions and high labour content in their products, labour cost reduction receives very high attention from the top management. For instance, an executive of an auto parts manufacturer commented that "labour accounts for a high proportion of the cost of the product, probably about 50%. Even though we have so much automatic equipment, our powerful union has made labour rates and other labour-related benefits extremely costly for the company. As a result, capital investments that can save labour costs tend to receive favourable treatment."

A number of interviewees also commented that their robots are not very flexible. Tremendous time and costs are required to adjust the robot to perform a different task. These robots are flexible only in the range of tasks that they are designed to perform, which is quite limited. The paired t-test confirms that labour-related factors are much more important than flexibility-related factors in robot justification. Thus, the strategic benefits suggested by the literature such as faster response to market needs cannot be realized by these robots. Consequently, using labour cost savings as a most important factor in justifying these robots are appropriate.

In addition to the "reduction of labour cost," "increasing cost of labour" is also an influential factor. There are two reasons to explain why the latter is not as important as the former: 1) many firms are becoming less competitive and are losing market shares. To recapture these, most of them are engaging in some sort of cost cutting programs; and, 2) to justify an equipment purchase by arguing that labour costs will increase in the future is harder than to justify it by using some existing figures such as current labour cost (i.e. reduction of labour cost justification). Although "increasing cost of labour" is harder to justify, it still receives some

attention due to the fact that most firms are highly unionized and management is very concerned about the increasing costs of labour in the future.

Further, the growing emphasis on quality of working life puts pressure on management to either increase the compensation for jobs that are tedious, repetitive and dangerous or to find ways to improve the quality of these types of work. "Employees unwilling to perform certain jobs" and "eliminate repetitive job" are perceived to have some degree of importance in the decision to invest in robots. It is probably due to the fact that since most of the robots in the sample are used to substitute for welding and lifting of parts in unpleasant environments, the repetitive and dangerous nature of the tasks have made these two factors influential.

As mentioned above, quality of working life has been receiving a lot of attention. On the other hand, management is unwilling to increase compensation for those unpleasant jobs like welding. Consequently, firms are unable to recruit the skilled labour needed to perform those tasks. This exerts some influence on the firm's decision to replace labour by robots performing those tasks.

The above findings provide some support to the literature's position that labour cost savings are the main reasons for investing in robots. It seems that firms put a lot of emphasis on the labour saving function of the robots. Given the paired t-test result also indicated that labour-related factors are much more important than flexibility-related factors, the answer to the research question, "is the majority of firms considered labour cost savings most influential consideration in robot investment" is "yes."

9.2 Flexibility assumption

The importance of intangible benefits, especially increase in flexibility, in AMT justification has drawn much attention in the literature. Many researchers feel

that increase in flexibility is of strategical importance but much harder to quantify and, therefore, often ignored in AMT justification.

As Kaplan noted "[AMT's] flexibility also gives it usefulness beyond the life cycle of the product for which it was purchased. True, in the short run, [AMT] may perform the same functions as less expensive, inflexible equipment. Many benefits of its flexibility will show up only over time. Therefore, it is difficult to estimate how much this flexibility will be worth" (1986:87).

Gold pointed out that managers "do not realize that CAM is a special kind of technology, whose adoption requires a broader level of analysis than that normally applied to the purchase of equipment and facilities" (1982:90). More directly, Primrose commented that managers are unable to "quantify the numerous intangible benefits flowing from flexibility" (1986:32).

From the above quotes, it can be seen that the literature's position is clear: flexibility is of strategical importance which should be, but has not been, properly incorporated in the AMT decisions. A more pessimistic view is given by Michael and Millen "if the proposed automation fails to clear hurdle rates, then the manager who still wishes to pursue the issue has no immediate resource, but to resort to a non-quantitative strategic justification approach. Unfortunately, this manager will likely find that strategic justification is oftentimes unappreciated by senior financial executives reared over the years on a diet of quarterly profit statements and equity price performance ... short of abandoning hopes for automation, no other options are immediately available" (1984:15).

An answer to the following research question will enable us to know whether such pessimistic view still holds:

Are those firms that invested in AMTs trying to increase their production

flexibility so as to produce goods at a cheaper cost and faster rate?

The answer to this question would be "yes" if one finds that the majority of firms considers flexibility-related factors most important considerations in the AMT decision.

The flexibility that AMTs offer takes several forms. First, the benefits of economies of scope, i.e., the ability to have low-cost production of high-variety, low-volume goods, are becoming more apparent as some firms are able to service after-market sales for discontinued models on the same equipment used to produce current high-volume models. Also, more customized production on the same lines used for standard products can be performed.

Second, in addition to the flexibility of moving away from mass production of standard products to the mass production of diverse products, the flexibility of AMTs can be in the form of reducing design and production time by easily accommodating engineering change orders and product redesigns. If the mix of products demanded by the market changes, AMTs can respond with a new product mix quickly since previous designs or programs can be retrieved and changed easily.

Third, flexibility can also be in the form of accelerating the speed and reducing costs of retooling for design changes.

Fourth, AMTs reprogramming capabilities make it possible for the machines to serve as backup for each other. Thus, AMTs can easily adjust production volume to handle unanticipated demand changes.

Fifth, given the above benefits, the need to carry excessive inventory to avoid stockouts is no longer necessary.

These 5 forms of flexibility are now investigated separately. Page 4 of the questionnaire asked the respondents to give ratings to each of these 5 factors. Thus, the

summary statistics of these ratings can be generated. More importantly, the null hypothesis of each of the 5 forms can be tested. As an example, the null hypothesis of the first form is:

More than 1% of the firms consider the ability to move away from the mass production of a standard product to the mass production of diverse products a most influential consideration in AMT investment.

If the null hypothesis with $t \geq 50\%$ is not rejected, one can conclude that the flexibility of being able to produce high-variety, low-volume goods is a most influential factor in AMT decision; otherwise, if the null hypothesis is rejected, the pessimistic views held by the researchers should be seriously questioned since, contrary to the literature, most firms do consider flexibility a most influential consideration. The other four forms are tested in a similar manner.

As in the case of labour-related factors, correlation analysis is performed to uncover any possible relationships between firm specific attributes and the importance of the flexibility-related factors.

Summary Statistics

TABLE 9.5: AVERAGE SCORE (STANDARD DEVIATION) OF FLEXIBILITY-RELATED FACTORS

	E1	E2	E3	E4	E5
TOTAL	2.45 (1.50)	3.68 (1.36)	3.32 (1.55)	3.05 (1.46)	2.82 (1.47)
CAD/CAM	2.80 (1.55)	4.50 (0.53)	3.90 (1.20)	3.10 (1.60)	3.10 (1.60)
ROBOT	1.70 (1.06)	2.70 (1.42)	2.50 (1.65)	2.70 (1.34)	2.20 (1.14)

*corresponding to the factor in the questionnaire. For example, F2 is shorter design and production time.

**includes two FMS firms.

Table 9.5 presents the results of the questionnaire concerning the 5 forms of

flexibility for the aggregate sample (22 firms) as well as for the CAD/CAM and the robot subsamples (10 firms each).

Among the 5 forms of flexibility in the aggregate sample, "shorter design and production time"(F2), "accelerate the speed and reduce cost of retooling for design changes"(F3) and "ability to adjust production volumes to handle unanticipated demand changes"(F4) have average scores slightly higher than 3, indicating that respondents, on average, viewed these factors as influential but not to the point of very influential.

The low ratings of these three factors are due to the "cancelling effect" of the CAD/CAM and the robot subsamples. The former has very high scores, close to or higher than 4, whereas the latter has low scores in all of the three factors. Due to this high inter-group difference, separate analysis of each group is needed to obtain meaningful results.

Cursory examination of the descriptive statistics of the CAD/CAM subsample provides a picture that the second and the third form of flexibility show certain degrees of importance. In fact, "shorter design and production time" has an average score of 4.5, indicating that most firms considered this factor most influential. "Accelerate the speed and reduce cost of retooling for design changes" also has a score very close to 4, indicating that many firms considers this factor very influential. However, none of the 5 forms of flexibility shows any importance in the robot subsample.

In order to substantiate the above comments, statistical tests are used to determine whether the majority of the firms considers the flexibility-related factors most influential.

Testing of hypothesis

Cumulative binomial probabilities for each of the flexibility-related factors are obtained in a similar fashion as described in Section 9.1. The number of firms

which consider the flexibility-related factors most influential is shown in Table A8.1 of Appendix 8. Table 9.6 shows the upper limits of the number of firms that the null hypothesis cannot be rejected for $\alpha = 0.05, 0.10$, and 0.20 values.

For the aggregate sample, "shorter design and production time" has the highest upper limit in which the null hypothesis that 45% or more (i.e. $t \geq 45\%$) of the firms consider that factor most influential cannot be rejected. However, the null hypothesis that 50% or more (i.e. $t \geq 50\%$) of the firms consider that factor most influential can be rejected. Other factors can be rejected in lower t value than that of the "shorter design and production time." Thus, for the aggregate sample, it can be concluded that a majority of the firms does not consider flexibility as a most influential factor. However, as explained above, the results may be due to the "cancelling effect." Thus, the examination of the null hypothesis in the two subsamples is needed.

TABLE 9.6: SUMMARY OF THE UPPER LIMITS OF NUMBER OF FIRMS IN THE BINOMIAL PROBABILITY TEST OF THE FLEXIBILITY-RELATED FACTORS*

	F1	F2	F3	F4	F5
<u>TOTAL(N=22)**</u>					
$\alpha = 0.05$	6(0.27)	10(0.45)	8(0.36)	6(0.27)	6(0.27)
$\alpha = 0.10$	5(0.23)	9(0.41)	8(0.36)	5(0.23)	5(0.23)
$\alpha = 0.20$	4(0.18)	8(0.36)	7(0.32)	4(0.18)	4(0.18)
<u>CAD/CAM(N=10)</u>					
$\alpha = 0.05$	4***	8	5	4	4
$\alpha = 0.10$	4	7	5	4	4
$\alpha = 0.20$	3	6	4	3	3
<u>ROBOT(N=10)</u>					
$\alpha = 0.05$	0	0	3	0	0
$\alpha = 0.10$	0	0	2	0	0
$\alpha = 0.20$	0	0	2	0	0

* Number in each cell indicates the upper limit of the number of firms that the null hypothesis, of considering flexibility-related factors most influential, cannot be rejected.

**includes two FMS firms.

*** % of firms are not given since it is just the number divided by ten.

In the CAD/CAM subsample, null hypothesis with $t \geq 50\%$ cannot be rejected

for the forms "shorter design and production time" and "accelerate the speed and reduce cost of retooling for design changes." "Shorter design and production time" is so strong that even the null hypothesis with $t \geq 80\%$ cannot be rejected. This implies that there are 5% of the chance in the population that firms consider these 2 forms of flexibility most influential considerations. For the other 3 forms, null hypothesis with $t \geq 40\%$ cannot be rejected; however, they do not pass the $t \geq 50\%$ mark. Thus, one can conclude that a minority of firms considers these 3 forms influential but the null hypothesis of a majority of firms considers them most influential is rejected. These findings indicate that the literature's criticisms are not totally accurate on the CAD/CAM subsample. More detailed discussion of the contradiction between the actual findings and the literature's position is presented later.

In the robot subsample, however, the null hypothesis with $t > 0$ can be rejected for 4 of the 5 forms of flexibility. "Accelerate the speed and reduce costs of retooling for design changes"(F3) is the only factor that shows some importance. However, the upper limits that null hypothesis cannot be rejected is 30% of the firms. Thus, it can easily be concluded that flexibility-related factors are not important at all for the majority of the firms in the robot subsample. Superficially, this supports the literature's criticisms. However, given that the type of robots that are used in the sample firms and the type of robots discussed in the literature are different, it may be inappropriate to conclude that the literature's criticisms are applicable here. Further discussion on this paradox is presented later.

Again, correlation analysis is used to find out whether there is any relationships between flexibility and the three firm specific attributes: number of employees, annual sales, and the cost of investment.

One may conjecture that the larger the firm the higher the complexity and the

higher the demand for production flexibility. Also, large firms usually have big inventory build up. In today's environment, minimizing inventory tend to be an effective way of cutting costs; thus, production flexibility is getting more important for large firms.

It is also safe to assume that the higher the cost of the investment, the more sophisticated the equipment is and the more likely that the equipment will enhance the firm's production flexibility. However, one has to be aware of the fact that AMT's are not always purchased for their most important features.

To determine whether the above conjectural relationships hold, Table 9.7 depicts the correlation coefficient between the percentage contribution of flexibility to the AMT decision and the three firm specific attributes. As can be seen, all correlation coefficients in the aggregate sample are very low, and less than 10%. The coefficients of the CAD/CAM subsample and the robot subsample show some degree of relationships. Thus, the null hypothesis that there is no correlation has to be tested. Using the test statistic and decision rules specified in the above section, it is found that the null hypothesis cannot be rejected in any case but one. In other words, there is no linear relationship between flexibility and the firms specific attributes in the aggregate sample and the subsamples, except for the one case which is discussed in the next paragraph.

In the robot subsample, correlation between sales and percentage contribution of flexibility is found to be 62.7%. The null hypothesis of no correlation is rejected. Thus, one can conclude that the larger the sales volume, the more likely is the firm to invest in robots for production flexibility. The positive relationship between sales and flexibility suggests that firms with high sales are concerned with their inventory turnover rate. Since the higher the turnover rate, the lesser the

inventory carrying cost, robots may be adopted to increase flexibility so as to reduce the need to carry large inventory. Unfortunately, other conjectural statements are not supported by the correlation tests.

TABLE 9.7: CORRELATION RESULTS OF FLEXIBILITY-RELATED FACTORS

	<u>Aggregate Sample *</u>	<u>CAD/CAM subsample</u>	<u>Robot Subsample</u>
Number of Employees	-0.023	-0.222	0.180
Annual Sales	-0.031	-0.217	0.627**
Cost of Investment	-0.063	0.155	-0.039

* include 2 FMS firms.

** The null hypothesis of no correlation is rejected.

Finally, as have been discussed in the above section, the paired t-test shows that flexibility is less important than labour-related factors in the robot subsample and the equal importance of labour-related factors and flexibility cannot be rejected in the aggregate sample and the CAD/CAM subsample.

To achieve a meaningful discussion on the importance of flexibility in the AMT decisions, the CAD/CAM and the robot subsamples are discussed separately below.

CAD/CAM Analysis

The average scores and the cumulative binomial probabilities have shown that "shorter design and production time" and "accelerate the speed and reduce cost of retooling for design changes" can be considered as very important factors in AMT decisions. In fact, "shorter design and production time" has the highest average score and upper limit of cumulative binomial probabilities than any other factor in the questionnaire.

In the subsample of 10, 5 rated "shorter design and production time" as most influential and the other 5 rated it very influential. Many of the interviewing firms engage in the production of custom-made industrial products. They realize that quite a number of their customers have switched to the just-in-time technology or other

inventory cutting technologies. Consequently, the demand volatility increases significantly.

As the president of a medium size company said, "flexibility is becoming very important as more companies are using JIT [just-in-time] which require us to deliver products in a specific quality and at a specific time within a short notice."

In other words, in order to satisfy the industrial customers, the supplying firms have to be flexible enough to meet the delivery schedules. To be able to meet a delivery schedule of a highly fluctuating demand pattern, most firms invested in CAD/CAM in order to obtain a "shorter design and production time" so as to achieve a faster turnover rate.

The literature's position that firms have not been able to recognize the strategical importance of flexibility can be refuted. In fact, results have shown that firms are actually capturing the strategical benefits of CAD/CAM to make themselves more competitive.

The time and cost involved in production set-up and retooling have gradually gained more important positions in the machinery acquisition decisions. This is due to the shortening of product life cycles which has forced the firms to switch from the production of one product to another more often. Consequently, manufacturers that can switch more quickly from one product to another without incurring high costs have a competitive edge over other manufacturers. In the sample, many firms are in fact striving for this competitive edge. The owner of a medium size, parts and components supplier explained : "The company can produce small and large parts with high precision. This has allowed us to compete in the two markets and increase our market shares. More importantly, we can switch back and forth to meet the changing demand of these two markets."

Again, one can see that many firms place important emphasis on the ability to "accelerate the speed and reduce cost of retooling for design changes" in capital equipment investment.

In addition to the above two factors which are considered most influential, some interviewees have expressed that the ability to increase product options and increase the variety of the same product are influential factors. However, they only give low ratings to the factor "move away from mass production of standard products to mass production of diverse products." This is because 80% of the CAD/CAM firms are not mass producers and are already producing custom-made products. Consequently, if they had been asked to rate "increase product variety and options," the results might have been different.

However, the interview results seem to support the literature's position that many firms have not yet recognized the importance of this feature at the time of evaluation. The comment by the president of a manufacturer of CNC machines seems to be representative: "Increase in product option and varieties are important but are only minor factors in the decision since they are long term things. We know that once we get accustomed to the machine we will be able to explore the power of the machine, i.e. opening up a variety of the options."

The low ratings given to the last 2 forms of flexibility are quite incomprehensive. It is because the high score on the "shorter design and production time" suggested that firms have the need to meet the volatility of demand. Thus, "ability to adjust production volumes to handle unanticipated demand changes" should naturally be important as well. However, since most of the firms are producing custom-made products, each order is of specific quantity and each order is different. Thus, the main concern of the firm is to finish the production of the order as soon as it can, unlike

producers of standard products which have to produce more in high demand times and less in low demand times.

Again, since manufacturers of custom-made products do not usually carry inventory, "reduction of inventory carryover" not being an influential factor is justified.

In sum, the literature's position on the industry's perception of flexibility is partially refuted and partially supported. In other words, there is no definite answer to the research question: *"Are those firms that invested in AMTs trying to increase the production flexibility so as to produce goods at a cheaper cost and faster rate?"* The majority of the firms has recognized the strategical importance of "shorter design and production time" and "accelerate the speed and reduce cost of retooling for design changes," and, in fact, these are very important in their decisions to invest in CAD/CAM. Thus, the literature's position on these 2 forms of flexibility is refuted. However, many firms do not place enough emphasis on the CAD/CAM's capability to increase product options and varieties at time of evaluation. This supports criticisms by the literature.

Robot Analysis

Overwhelmingly, flexibility is not considered to be influential in the decision to acquire robots. Average scores for all 5 forms of flexibility are below neutral and the binomial probability tests show that only "accelerate the speed and reduce cost of retooling for design changes" cannot be rejected in the $t > 0$ level (i.e. none of the firms in the population considers the factor most influential in the population). The null hypothesis that "accelerate the speed and reduce cost of retooling for design changes" considered by a majority of the firms to be most influential, however, can easily be rejected. Results of the paired t-test above confirm this finding by indicating

that labour-related factors are much more important than flexibility-related factors.

A few firms, however, have recognized the importance of flexibility. One firm reported that they can now accept subcontracting work to use up the slack capacity due to the robots' capability to switch from one product to another quickly and cheaply. Another reported that "[robot's flexibility] is becoming more and more important because the cost of capital equipment is so high and the product life cycle is so short. Thus, if the equipment cannot be used for other product lines when the old product line phases out, the equipment will become obsolete and we will suffer loss in capital investment."

Given the robots that are used by the sample firms are not as sophisticated as those discussed in the literature, the lack of enthusiasm on flexibility is partially justified. However, the flexibility is still present in the robots of these sample firms and they should have put more emphasis on the versatility of the robots. Thus, some of the literature's criticisms are valid but one has to be very cautious in using the literature's criticisms of the robot adoptors since the robots usually mentioned in the literature are of a more advanced type. In short, for the robot firms, the answer to the research question: *"Are those firms that invested in AMTs trying to increase the production flexibility so as to produce goods at a cheaper cost and faster rate?"* is "no."

9.3 Status quo assumption

In a stable environment, firms can assume business will continue as usual and operate the same way as they did in the past. Equipment investment can be evaluated by measuring its incremental benefits over the current business figures. However, the growing internationalization of markets have aggravated competition both in domestic and foreign markets. AMTs are perceived to be dominant future manufacturing technologies. Firms that can capture them in the early stage will have a better

competitive edge than others in the future.

In fact, a study²⁵ shows that inefficient or outdated production technology, layout, or materials handling are the most frequently mentioned reasons for plant closing in the U.S. To survive, AMT investments should be evaluated in such a way that the firms should assume a situation of declining cash flows, market share, and profit margins if AMT investment is not taken. This is because even if the firm decides not to invest in AMTs, the likelihood is that some of its competitors will. In other words, as Henry Ford claimed, "if you need a new machine and don't buy it, you pay for it without getting it." To state it briefly, the issue is not, "what is the ROI of this piece of machinery if we continue to go the way we've gone in the past?" but rather, "what would be the ROI of our factory five years from now if we don't invest in the new equipment while still trying to meet the market demands of the future?"

Many researchers believe that the majority of firms is assuming business will continue as usual. As Kaplan wrote, "companies also commonly underinvest in CIM [computer integrated manufacturing] and other new process technologies because they fail to evaluate properly all the relevant alternatives. Most of the capital expenditure requests I have seen measure new investments against a status quo alternative of making no new investments -- an alternative that usually assumes a continuation of current market share, selling price, and costs. Experience shows however, that the status quo rarely lasts. Business as usual does not continue undisturbed" (1986:87).

Goldhar and Jelinek went further to say that, "dominated by obsolete assumptions, many managers assume the investment being analyzed is simply a direct replacement for the old equipment, has a narrowly defined impact and is a fixed technology that will not change. New technology is evaluated against what production costs would have been last year, had we been using the new machine. However, last

year's product mix was optimized for the constraints of conventional production facilities, and such a criterion wholly ignores the benefits of increased integration and improved flexibility... these advantages acquire central importance in light of current market change" (1985).

To examine whether the literature's criticisms on the manager's myopic view of assuming business will continue as usual are valid, the following research question needs to be answered: *"Is the measurement of AMT benefits done by comparing the current business extrapolates with the estimated results after installing AMT?"* The answer to this question would be "yes" if one finds that the majority of the firms holds this view.

However, in the interview situations, direct asking of this question directly will generate biased results. Therefore, a number of indicators are used to measure how sensitive the managers are to the changing business environment. Page 4 of Appendix 5 shows these indicators. If managers perceive "concern over product quality" as a very important factor, this will mean that they have recognized that the current business trend, which requires quality products, and the failure to produce quality products will result in the decline of business.

"Belief in the importance of flexible automation by top management" measures whether the decision makers have realized the importance of AMTs for future survival.

If the firms assume that business will continue as usual, they will not worry about markets being taken over by the competitors. Thus, firms with "a concern over the loss of market share to competition" are likely to assume that business will decline if AMTs are not adopted.

The firms would only have "a concern that the competition are automating" if

this affects their business. In this case, the firms are not likely to assume that business will continue as usual. Therefore, a high rating of one or more of these indicators will indicate that status quo assumption is not valid.

To verify the literature's criticisms, the average scores and the binomial probability tests of each of the 4 indicators are examined. The null hypothesis of these 4 indicators are set up in the same manner as those of the different forms of flexibility in the previous section. However, correlation analysis to uncover any possible relationships between the firm specific attributes and its ability to recognize business will not continue as usual is not possible due to the questionnaire design. As explained before, a firm's ability to recognize business will not continue as usual cannot be asked directly. Thus, as shown on page 5 of the questionnaire, interviewees are only asked to indicate the percentage contribution due to labour, flexibility and other factors that they feel appropriate. Consequently, no correlation analysis can be done.

Summary Statistics

Table 9.8 displays the average score of the 4 indicators of the firms' ability to recognize AMTs capability to help them to survive in the changing business environment.

TABLE 9.8: AVERAGE SCORE (STANDARD DEVIATION) OF STATUS QUO-RELATED FACTORS

	<u>S1*</u>	<u>S2</u>	<u>S3</u>	<u>S4</u>
TOTAL**	4.05 (1.17)	4.05 (1.13)	3.14 (1.46)	2.86 (1.52)
CAD/CAM	3.90 (1.29)	4.00 (0.94)	2.90 (1.45)	2.60 (1.35)
ROBOT	4.10 (1.97)	3.90 (1.37)	3.00 (1.41)	2.70 (1.57)

*corresponding to the factor of the questionnaire. For example, S1 is "concern over product quality."

**includes two FMS firms.

Among these 4 indicators, both "concern over product quality"(S1) and "belief in the importance of flexible automation by top management"(S2) have average scores of 4.05, indicating that, on average, the firms' perceived these two factors very influential. However, "a concern over the loss of market share to competition"(S3) and "a concern that the competition are automating"(S4) only have average scores close to neutral, indicating that, on average, firms do not consider these factors relevant in the AMT decisions.

Different from the labour- and flexibility-related factors, the scores of the CAD/CAM and robot subsamples are very similar for all of the 4 status-quo related factors.

Testing of hypothesis

Again, upper limits of the number of firms that the null hypothesis cannot be rejected for each of these 4 indicators are shown in Table 9.9. The results are consistent with Table 9.8. Among these 4 factors in the aggregate sample, the null hypothesis that a majority of firms considers "concern over product quality" and "belief in the importance of flexible automation by top management" most influential cannot be rejected. The other 2 factors, however, can be rejected in very low t values.

The results of the two subsamples are very similar and only differ in magnitude. Test results of "concern over product quality" are identical in both subsamples. However, 70% or more of the firms consider "belief in the importance of flexible automation by top management" most influential cannot be rejected in the robot subsample whereas only 50% or more in the CAD/CAM subsample cannot be rejected. Also, the null hypothesis with $t > 0$ for the last two factors can be rejected in the CAD/CAM subsample whereas null hypothesis with $t \geq 30\%$ can be rejected in the robot subsample.

Both the average scores and the binomial probability tests have indicated that the difference of the CAD/CAM and the robot subsample is small. Therefore, a combined analysis is used to replace the usual separate discussion of these two subsamples.

TABLE 9.9 SUMMARY OF THE UPPER LIMITS OF NUMBER OF FIRMS IN THE BINOMIAL PROBABILITY TEST OF THE STATUS QUO-RELATED FACTORS*

	<u>S1</u>	<u>S2</u>	<u>S3</u>	<u>S4</u>
<u>TOTAL(N=22)**</u>				
$\alpha = 0.05$	13(0.59)	13(0.59)	6(0.27)	6(0.27)
$\alpha = 0.10$	12(0.55)	12(0.55)	5(0.23)	5(0.23)
$\alpha = 0.20$	11(0.50)	11(0.50)	4(0.18)	4(0.18)
<u>CAD/CAM(N=10)</u>				
$\alpha = 0.05$	7***	5	0	0
$\alpha = 0.10$	6	5	0	0
$\alpha = 0.20$	5	4	0	0
<u>ROBOT(N=10)</u>				
$\alpha = 0.05$	7	7	3	3
$\alpha = 0.10$	6	6	2	2
$\alpha = 0.20$	5	5	2	2

* Number in each cell indicates the upper limit of the number of firms that the null hypothesis, of considering status quo-related factors most influential, cannot be rejected.

**includes two FMS firms.

*** % of firms are not given since it is just the number divided by ten.

Combined Analysis

The above results indicate that AMT investments are heavily influenced by the top management's belief in the importance of flexible automation and AMTs' ability to produce high quality products. However, firms are not concerned that failure to invest in AMTs will lead to a loss of market share to the competition nor are they concerned that the competition is automating.

Many researchers have expressed that their customers are increasingly demanding in quality. Their survival depends on their ability to improve quality so as to satisfy their customers. The president of an auto parts supplier expressed that: "The technology to produce a better quality product is available. Both our competitors and

our customers know about this. If we do not invest in it, our competitors will. The long term effect is clear."

Many firms have recognized that product defects and rejects are very costly both in terms of production and sales. Quality control technologies such as "Total Quality Control" and "Statistical Processing Control" are used. Due to the emphasis on quality, these industries require high quality inputs. As many firms in the sample are supplying parts and components to these firms, they have recognized that their future business depends upon their ability to keep pace with their customers' increasing demand for higher quality. Consequently, they put strong emphasis on product quality in capital investment.

Top management's belief in AMTs is a strong indication of the firm's realization of the changing business environment. In the sample, 18 out of 22 firms indicated that "belief in the importance of flexible automation by top management" is a very influential or a most influential factor. Verbal statements provided by the respondents have thrown some light on the underlying rationale of their belief.

Some typical responses include: "many firms have acquired similar systems and the delay in acquiring the technology would leave us behind the competition," and "in this fast changing environment, the only way to survive is to be constantly upgrading our production technology."

In addition to the verbal statements, the quantitative methods used by the firms to evaluate AMT investments also provide some hints. It is found that almost all the firms only compare current costs with the expected costs using AMTs. However, an auto parts supplier has used a spreadsheet to do sensitive analysis of different scenarios by assuming constant, increasing, and decreasing demands. For each scenario, the incremental benefits of AMTs over current technology are calculated.

As the future business environment is unknown, it is not surprised to find that most quantitative analysis are based on past data. This does not directly imply that managers implicitly made the status quo assumption. This is because if the quantitative analysis is used in conjunction with the qualitative analysis, the estimation of changing business environment can be done in the latter analysis.

The low ratings of the last 2 indicators, "a concern over the loss of market share to competition" and "a concern that the competition are automating," can be explained in two ways. First, many firms in the sample are early adopters of the AMTs. Instead of following the competitors, they are the first ones employing the new technology to create a better competitive edge over their competition and to capture market share from the competitors. Second, there is a lack of understanding of the long term effect of AMTs. Although they have decided to invest in AMTs, they do not believe that failure to invest in AMTs will lead to a decline in market share. As the president of a sheet fabricator pointed out, "we have a stable market share and unless we cannot meet our customer's requirement, we will not lose our market share."

From the above analysis, one can see that the 4 indicators of whether firms made status quo assumptions give conflicting results. However, based on the strong results of "concern over product quality" and "belief in the importance of flexible automation by top management," one cannot refute the argument that firms' have recognized that they are operating in a very volatile and competitive environment, and future survival is a main motivation for their investment in AMTs. Therefore, the literature's criticisms are not entirely acceptable. Although firms do not incorporate the consequences of not investing in AMTs in their quantitative analysis, they do so in the qualitative analysis.

The literature's criticisms are correct in the sense that firms do not pay

enough attention to their competitors' actions. Many firms reported that they either do not care or do not know the moves of their competitors. Also, the firms seem to underestimate the seriousness of not adopting AMTs. Thus, the literature's criticisms are partially supported.

9.4 Capital budgeting technique assumption

One of the criticisms put forward by researchers is that the emphasis on Discounted Cash Flow methods for financial justification is a major barrier to the introduction of AMTs. As Michael and Millen puts it, "investment in such modern manufacturing technologies may be a strategic necessity similar to support of a product research program. Yet, these same companies are generally basing their investment decisions upon traditional DCF financial justification methodologies best suited to meet short term profitability criteria than long term strategic goals" (1984:35).

In a conference²⁶ on the justification and acquisition of new technology, Gold criticized the fact that DCF methods are too static and the evaluation horizon used by the managers are too short. Also, he commented that the use of high hurdle rates has made the potential profitable long term projects unfavourable.

The static nature of the DCF methods received many criticisms from the literature. As Goldhar and Jelinek commented, "older methods of capital appropriation evaluation [DCF methods] ignore the strategic, integrative character of the new technology" (1985). This is echoed by Kaplan(1986).

The inability of DCF methods to capture strategic importance of AMTs has received thorough discussion in previous sections. The integrative character of AMTs, however, warrants some discussions here. Gold stressed that "the real promise of CAM technology lies not in its use as yet another, perhaps fancier than usual, machine tool located at a single point in an otherwise unchanged production process. CAM's promise

lies, by contrast, in its ability to integrate adjacent operations with each other and with overall control systems. Because it offers a systemic -- not a "point" -- capability, neither its purchase nor performance should be evaluated in the traditional way" (1982:88). This view is shared by Van Blois (1986).

In general, researchers feel that DCF methods are commonly used in the industry and they are not working properly in evaluating AMTs. The major perceived defaults are: 1) the inability to incorporate non-quantifiable factors, especially those strategic factors and the integrative character; 2) the use of high hurdle rates making long term projects undesirable; and 3) the short evaluation periods that underestimate the long term benefits of AMTs.

These criticisms are only valid if DCF methods play a major role in the evaluation process. Thus, this section examines the research question: *"What is the role of DCF methods in the AMT investment decisions and what other methods, if there are any, are used to supplement the inadequacy of capital budgeting techniques?"* By examining this, it is hoped that we can throw some light on the validity of the criticisms of managers. The cumulative binomial probability test of proportion is used to test the null hypothesis:

More than t% of the firms used DCF methods in their AMT justification process ?

If the null hypothesis with $t \geq .50$ is not rejected, this will imply a need to investigate how the DCF methods are used in order to determine the validity of the literature's criticisms. However, if the null hypothesis is rejected, the view held by many researchers that the use of DCF methods is the major barrier to AMT investment can be refuted.

In both scenarios, different capital budgeting techniques used by the firms are

analyzed in detail. These Capital Budgeting Techniques (CBTs) may include the two most common types of DCFs: Net Present Value and Internal Rate of Return, the Payback Rule and the Return On Investment techniques. These techniques and their characteristics have been discussed in Section 3.2. Also, the criticisms such as short evaluation horizon, and failure to consider strategic factors are examined to see whether they are valid in the different evaluation methods.

Summary Statistics

Table 9.10 shows how DCF methods are used by the sample firms. Among 22 firms, only 8 reported that they use DCF methods in their evaluation process. Of these 8 firms, 3 used DCF methods as the dominant technique and the other 5 reported that the methods only played a minor role in the evaluation process. The rest of the 14 firms did not use capital budgeting techniques.

TABLE 9.10: THE USAGE OF CAPITAL BUDGETING TECHNIQUES

	<u>TOTAL*</u>	<u>CAD/CAM</u>	<u>ROBOT</u>
<u>Usage of CBTs:</u>			
Not used	14	9	5
Minor role	5	1	2
Major role	0	0	0
Dominant role	3	0	3

*includes two FMS firms.

The table also shows that 9 out of 10 CAD/CAM firms did not use capital budgeting techniques. The only CAD/CAM firm that used a type of capital budgeting technique reported that it only played a minor role in its evaluation process. The robot subsample, however, depicts a somewhat different picture: half of the firms reported that they used capital budgeting techniques in their robot investment decisions. Of which DCF methods played a minor role in 2 firms and a dominant role in 3 firms. The 2 firms in FMS also reported that they used DCF methods but their decisions were

strongly based on the strategic need of the company.

To give a general picture of the quantitative techniques used by the sample firms, they are re-divided into 4 groups in Table 9.11. As can be seen, a total of 11 firms used payback: 6 from the CAD/CAM subsample and 5 from the robot subsample. The use of payback in conjunction with DCF methods is common in the robot subsample. However, one has to be cautious about the figures since they do not tell how important these techniques are in the process. For instance, DCF methods with payback can be used together but the strategic justification is more important than the results of these two techniques. Further analysis of how these techniques are applied will be discussed later.

TABLE 9.11 THE USAGE OF DIFFERENT QUANTITATIVE TECHNIQUES

	<u>TOTAL*</u>	<u>CAD/CAM</u>	<u>ROBOT</u>
No payback, no DCF	8	4	4
payback, no DCF	6	5	1
DCF, no payback	3	0	1
DCF and payback	5	1	4

*includes two FMS firms.

Testing of hypothesis

Table 9.12 shows the upper limits of the number of firms that the null hypothesis cannot be rejected. In the aggregate sample, the majority of firms using DCF methods cannot be rejected. However, as shown in the summary statistics, there are large inter-group differences. Separate examination of the null hypothesis in these two subsamples indicates that the majority of firms using DCF methods can be rejected in the CAD/CAM subsample whereas the null hypothesis cannot be rejected in the robot subsample.

Based on the summary statistics and testing of hypothesis, a few phenomenon are observed. First of all, payback is the most common type of capital budgeting

techniques used by the firms. Out of the 14 firms using capital budgeting techniques, 6 used only payback, 3 used only DCF methods, and 5 used both. For those that used DCF methods, internal rate of return is more common than the net present value method.

Secondly, the three subsamples have clear distinctions from each others. In the CAD/CAM subsample, DCF methods are generally not used. In the robot subsample, half of them used DCF methods and thus the DCF methods can be considered a common practice. In the FMS subsample, again, due to small sample size, one cannot draw a strong conclusion. However, both of the firms in the FMS sample used internal rate of return but the strategic justification is dominant over the internal rate of return.

TABLE 9.12: SUMMARY OF THE UPPER LIMITS OF NUMBER OF FIRMS IN THE BINOMIAL PROBABILITY TEST OF THE USE OF CBTS*

	<u>TOTAL**</u>	<u>CAD/CAM</u>	<u>ROBOT</u>
$\alpha = 0.05$	12(55%***)	3	8
$\alpha = 0.10$	11(50%)	2	7
$\alpha = 0.20$	10(45%)	2	6

* Number in each cell indicates the upper limits of the number of firms that the null hypothesis of considering flexibility-related factors most influential cannot be rejected.

**includes two FMS firms.

*** % of firms

Because of these differences, the CAD/CAM and robot subsamples which have larger sample sizes are analyzed separately below.

CAD/CAM Analysis

Due to the easier access of information from large firms than from small firms, research efforts tend to concentrate on the large firms. In particular, previous research found that DCF methods are commonly used in the industry. However, their results may not be applicable to the small and medium size enterprises.

Thus, it is not surprising to find that 90% of the CAD/CAM firms do not use DCF methods even though previous findings suggest that most firms use them. A number

of explanations of why DCF methods are not used can be advanced.

First of all, most of the firms are small to medium size: 80% of them have less than 200 employees and less than \$25 million annual sales. Consequently, most of their employees are involved in actual production and the number and variety of support staff are limited. Moreover, most of the top management of these small and medium size enterprises are technically trained and few have solid training in finance and accounting.

As a result, they usually do not have or do not need to have a rigid structure of capital budgeting. Rather, the top management makes investment decisions based on their business judgment. As the owner of a small manufacturer said, "I have a good feeling about the business and mentally estimate whether the increase in sales would support the cost of the machine."

Due to the lack of expertise in evaluating equipment investment, coupled with the lack of information about CAD/CAM benefits, many reported that CAD/CAM benefits are very uncertain and difficult to measure. Some comments from the respondents are sufficient to illustrate this point: "We tried to estimate the savings but at that point in time it was very uncertain about what CAD/CAM would save and hard to come up with accurate figures since we did not have the basis."

Also, the owner of a machine shop offered a very insightful comment on DCF methods: "I believe that investing in equipment is just like a chain of decisions. If one decision works, it will lead to another decision. Unless you make the initial decision, it is very hard to estimate the gain of subsequent decisions." In fact, Kester (1984) has suggested that managers think of investment opportunities as options on the company's future growth. Like call options on securities, growth options represent real value to the companies that possess them since they can build upon the current equipment in the

future whereas their competitors without the current investment cannot.

Although DCF methods are not used, some CAD/CAM firms use payback as their capital budgeting technique. Among the 10 CAD/CAM firms, 6 use payback and the other 4 are owner/manager types. As discussed in the owner/manager model in Section 9.4, the decision makers are the owners and their decisions are solely based on their judgment.

For those that use payback, many of them feel that the technique is simple and easy to use. More importantly, given the volatile nature of their business, they are hesitant to invest in something that does not pay back in a few years. Consequently, a very short horizon is used, ranging from one to three years. One owner explained that "We do not look at longer periods because more sophisticated CAD/CAM systems may come out and the old ones may become obsolete and we may have to invest in some new systems." In other words, technical obsolescence and capital constraints, in addition to uncertainty of future business, are the main reasons of using short payback periods.

In sum, the CAD/CAM firms do not use DCF methods. For the owner/manager type, "business judgment" without any quantitative techniques were used to make the CAD/CAM investments whereas the rest used payback with a short required period.

The criticisms that high hurdle rates are used and intangible factors are ignored in the DCF analysis are irrelevant here since DCF methods are not used. However, in order to use payback period, we still have to measure the quantitative benefits of CAD/CAM. The result is mixed: some firms do not find it hard to quantify the intangible benefits, some place more emphasis on qualitative evaluation, and others just ignore the intangibles.

The General Manager of a firm explained why intangibles like quality can be quantified. He said, "anything is quantifiable, for example, quality can be transformed

into fewer reworks and increased sales. It may take a while to figure them out but you definitely can put numbers on them."

In addition to quantifying the qualitative factors, some firms just place more emphasis on the qualitative evaluation such as looking at how the equipment can contribute to the company in terms of flexibility. For these firms, there is no strict payback rule.

Still others totally ignored the qualitative factors. For example, one executive said, "savings are only based on labour savings, although there are fringe savings like better quality of drawings, they are not considered in the cost justification."

From the above three types of firms, the first two types have properly treated the intangibles and, therefore, the criticisms of ignoring intangibles in the CAD/CAM investment evaluation is not valid. However, it is valid on the third type since qualitative factors are totally ignored.

It is also fortunate that due to their small size, many firms do not use DCF methods and have avoided the problems that DCF methods have caused to many large firms that are trying to justify investments in CAD/CAM.

Finally, the short payback period required by many companies have inhibited many profitable long term investments. Some interviewees have recalled that some similar investment proposals were rejected in the past due to the inability to meet the short payback period set by the company even though the proponents strongly believed that the investment would be beneficial to the company. The rationales given above by the respondents, although they lack theoretical justification, are practical problems facing many decision makers. Although the criticisms that short payback period caused the rejection of some long term profitable projects is valid, there is no immediate solution to provide a remedy for the present situation.

Robot Analysis

The use of DCF methods are quite popular among the robot firms -- half of the firms used them versus only one in the CAD/CAM subsample.

For the other half that do not use capital budgeting techniques, 3 firms present some special reasons. A large turbine manufacturer explained that their business is very volatile and every contract is very large. Therefore, they acquired equipment solely based on the requests of their customers as a prior term for signing contracts or because they believed that the equipment will help them to win confidence of the potential customers. Thus, quantitative techniques were not used. For the other 2 firms, the robot investments were just a part of larger investment and thus no separate evaluation for robots was performed. Therefore, the above three firms can be considered as special cases of not using DCF methods.

However, there are 2 firms which had no special reason for not using DCF methods. A small machine shop owner based all equipment acquisition decisions on business judgment whereas another railcar manufacturer expressed that payback is better than DCF methods.

Among the 5 firms that are using DCF methods, IRR was used in all cases. Executives justify their use of IRR by its ability to allow the comparison of the rate of return among different projects.

The use of IRR in these firms is just part of the evaluation techniques. In fact, 2 out of these 5 firms expressed that IRR only played a minor role in their robot investment decisions. Both of these firms used qualitative judgment in addition to the IRR.

For the other three firms, IRR played a major role in robot investment decisions. A division manager of a major electrical equipment manufacturer used high

IRR to justify the robot investment. Although NPV was computed, it was not used in the justification process. The engineering manager of a disc brake manufacturer used a spreadsheet to compute IRR, NPV, and payback period for 3 scenarios of sales: increasing, constant and decreasing. The high IRRs in all scenarios are then used to convince the top management to invest in the robots. Finally, the supervisor of the manufacturing engineering division of a machinery manufacturer used a special form prepared by the Machinery and Allied Products Institute for the evaluation of equipment acquisition. This form allowed the division manager to compute a similar version of IRR which was then used in the justification process. The specific procedures employed and the results of the DCF applications by these 3 firms are given in the Appendix 9.

Different from the CAD/CAM firms, the robot firms often used a longer evaluation horizon. All but one firm estimate the incremental benefits of robot use for a 10-year or longer horizon. In terms of discount rates, multiple rates are not used to compute NPV. All NPVs are computed by a single rate.

The widespread use of these DCF methods in the robot firms can be explained in two ways. First of all, the size of the robot firms are generally larger than the CAD/CAM firms. Thus, a more elaborated organizational structure is found and a standard way of evaluating investment is done to ensure proper allocation of funds. Also the larger size enables the use of expertise in finance and accounting. Consequently, DCF methods are used.

Secondly, a larger portion of the benefits of robots comes from labour savings which are easily measurable. Due to the quantitative nature of the labour saving benefits, DCF methods can be employed.

The use of DCF methods are not without problems. For some firms, the

problems do not surface since the quantitative benefits are large enough to generate favourable IRR. These firms, however, have recognized or suffered from the problems of DCF methods. As an executive recalled a similar robot investment was rejected due to the low IRR. Attempts have been made by the executives of these firms to convince the top management about the non-tangible benefits of the robot but without much success.

For the other firms, the inability to incorporate intangible factors has created bias against investment in robots. As one executive said, "anything that is not quantifiable such as quality improvement does not fit into the calculation of IRR ... anything that is not quantifiable is not considered very seriously since everything has to have a 3-year payback period."

Faced with the above problem when CBTs are used, executives cannot directly confront the problem by suggesting that CBTs should not be used in evaluation since most of the executives involved in the evaluation process are not in the top management level. Therefore, executives find a number of ways to "get around" the problem.

One respondent said, "since ROI cannot measure the qualitative factors that we believed to be very important and we are still using ROI, we have to 'cheat' or use 'creative accounting' to make the numbers in favour of the investment." Another executive admitted, "to get through the robots with low ROI but enhance quality and productivity, we group them into a project that has a very high ROI. By doing so, we will get not only the improvement in quality and productivity, but also an acceptable ROI, though it may be diluted by the robots."

As can be seen, the use of CBTs in evaluating robot investment is not without problems. In particular, the literature's criticisms of the inability of incorporating intangible factors in the evaluation are valid. The methods used by the managers may be effective but certainly not appropriate. However, it is the top management's

responsibility to devise a better procedure for evaluating capital investment. Kaplan's method of first looking at the quantifiables then the non-quantifiables may be a practical solution for some of these firms.

The criticisms of high hurdle rate are valid since most firms require the investments to have 20% or higher IRR and ROI. Again, many executives have to use "creative accounting" to get over this high hurdle. For example, a turbine manufacturer has set four different discount rates for investment with different risks, class A being the lowest risk (details are shown in Table 9.3, Appendix 9). The executive said, "we always try to move the project to class A risk since it is much easier to get it approved. Moreover, I do not want to tell the accountants that this is a very risky project and if I do, they will overreact."

Many firms felt that their future is very uncertain and a high discount rate ensures a fast capital turnover. However, such action leads to decline in investment in long term projects which will lead to a decline in the firm's capability to cope with the increasingly competitive markets of the future. Thus, this high hurdle rate, as suggested in the literature, is not appropriate.

The criticisms of short evaluation horizon, however, are not founded since most of the firms use a 10-year evaluation horizon.

In some literature, multiple rates are suggested as a solution for correcting the bias against investment in robots. However, this suggestion is impractical. This is because IRR is the most common form of DCF methods and NPV is rarely used. Thus, it is difficult to ask them to jump from the use of IRR to the use of NPV with multiple rates. Also, most firms are convinced that they are facing a very volatile environment and a high hurdle rate is justified. Thus, the priority should be to convince these managers that the high hurdle rate is not appropriate.

10. DISCUSSION AND CONCLUSIONS

We have seen in the course of this study that slow AMT adoption is an existing problem. Canadians must find ways to solve this problem in order to survive the growing competitiveness of the international markets for manufacturing products. A decline in manufacturing industries will create a spiral effect that may cripple the Canadian economy.

This study, however, is not intended to provide a solution to the problem of slow AMT adoption. Rather, what this study does is to provide a better understanding of the entire decision making process, and to verify four important research assumptions in the study of AMT investment decisions. These are essential prior to the identification of appropriate solutions to cure the slow adoption problem.

To conclude, some biases and limitations of this study are discussed. Having these in mind, the contributions of this study are summarized. The validity of the research assumptions and the practicality of the evaluation models are then reviewed. Finally, some suggestions to the decision makers in the industry to correct the biases against the AMT investment decision making process are advanced and some future research directions are recommended.

10.1 Biases and limitations

As in much social science research, it is impossible to obtain "pure truth" that does not have any bias and limitation. Therefore, prior to the discussion of the contribution, it is important to know the biases and limitations of this study.

In an ideal situation, the best way to study the AMT decision making process and its bias against the adoption of AMTs would be to compare two groups of firms that have considered the possibility of investing in AMTs: one group finally decided to invest whereas the other group rejected the investment proposals. By having such a control

group, the examination of the research assumptions would be unbiased. In this study, since all the firms have decided to invest, it is quite likely that their decision making processes have less biases against AMTs than that of the firms that choose after consideration not to invest. However, given the scope of this study and the difficulty in identifying firms that have considered but rejected AMT investments, the research design employed is believed to be suitable.

In the setting up of the research design and sampling plan, it has not been anticipated that the inter-group (CAD/CAM, robot, and FMS) differences are large. The plan was to analyze all AMT investments as a group and the analysis of inter-group differences were to be only a minor part of the study. At that time, this assumption was appropriate since most of the current research in this topic has not indicated that there were major differences in the decision making process among these technologies.

In fact, most of the criticisms are targeted at the manufacturing technologies labelled "flexible automation," "advanced automation," "new manufacturing technologies" and "advanced manufacturing technologies." These labels most often refer to CAD/CAM, robots, and FMS. Based on the assumption that inter-group differences are not large and the number of FMS installations are limited, only 2 FMS firms are selected for interviews. Moreover, due to the pioneer nature of the investments, the executive of one of these two firms preferred to be interviewed by telephone. Thus, the quality of the responses from FMS firms are not as good as those that are collected from the CAD/CAM and robot firms. As a result, this study is not able to provide detailed comparison between FMS and the other two types of technology since such comparison may not have internal validity²⁸ due to the small sample and the low quality of FMS responses.

Because of the lack of research of AMT investment in Canada, most of the

research assumptions are extracted from U.S. studies which are not directly targeted at Canadian firms. Thus, the comments on the validity of research assumptions are not intended to discredit the research findings. Rather, the main motivation is to see how valid are those assumptions applied in the Canadian context.

Also, given that the sample is randomly selected from the population of firms that have adopted AMTs, the external validity²⁹ of the study to generalize results across those that have adopted AMTs should not be questioned. However, one must be very careful in generalizing the results of this study across different time periods. This is because most of the firms in the sample are early adopters of AMTs. A few years later, when AMTs become more mature and savings are easier to estimate, the results of this study may not be as applicable as it is now. This is due to the fact that late adopters may have different characteristics from the early adopters.

Finally, all the firms in the sample are from Ontario. It is likely that Ontario firms are different from firms in the other provinces. If such differences are large, the mere use of Ontario firms may not produce results to represent the situation of Canada in general. However, given that Ontario produces over half of the country's manufacturing goods, and has more robots, CAD/CAM, and FMS installations than all other provinces combined, use of the Ontario firms in this study can be considered as a representative sample.

10.2 Contributions of the study

The slow adoption of AMTs has long been recognized as a major threat to the survival and competitiveness of the Canadian manufacturing industries. Government agencies, universities, professional associations, and other interest groups have tried to find ways of removing barriers to the adoption of AMTs. Most of their efforts have concentrated on finding out the causes and trying to provide solutions to the problem. So

far, they have successfully identified some of the causes of slow AMT adoption, notably, the problem of financial justification of AMTs. A large volume of research work is then produced to criticize the justification process but much of this research work echo one another's view and are not substantiated with facts. These efforts have not led to the development of feasible and practical solutions that can be used to improve the fairness of the AMT evaluation procedure.

The existence of this gap -- between the recognition of the causes of the slow adoption problem and the identification of suitable solutions -- is likely caused by the lack of indepth understanding of the actual decision making process used in the evaluation of AMTs in the industry.

Much of the research work is of general nature. It usually ignores the influence of firm size, type of industry, production method or other factors that are likely to affect the evaluation procedure. Moreover, little attention to the patterns or trends of AMT adoption is given. Thus, the criticisms are not effectively addressed, since the knowledge of the type of firms that are likely to have problems in evaluating AMTs is limited. Due to the inadequate knowledge of the industry's characteristics, models that are built for evaluation of AMTs are of general nature and, thus, their practical implications are severely limited.

Researchers have made many unsubstantiated, but not necessarily invalid, research assumptions, such as manager's over-emphasis on labour cost savings and lack of emphasis on flexibility, in expressing their views of the problem of slow AMT adoption or in suggesting solutions to the problem.

Also, the narrow focus on the justification process is very dangerous since a total view of the decision making process is lacking. This is because the biased justification process may well be a symptom of the problem of slow AMT adoption. The

causes of the problem could be in the earlier stages of the decision making process, such as at the search routine where the decision makers are not able to identify a suitable and profitable capital investment.

Thus, although a number of models are suggested for use in AMT evaluation, their validity and usefulness must be questioned, since they are based on unsubstantiated assumptions and have a narrow focus on the evaluation stage.

This study has four main contributions that may help to narrow the gap between the recognition of the causes of the problem and the identification of practical solutions.

Summary of Literature

From the business perspective, a careful examination of the current literature on the adoption of AMTs is carried out. It is found that:

- 1) there is an imbalance between the efforts spent on survey articles and analytical articles;
- 2) there is a research direction towards the establishment of models to help managers to better evaluate the AMT investments; and
- 3) there are a number of different viewpoints with regard to the underlying causes of the slow AMT adoption.

Most of the survey articles on AMT adoption are outdated. The recent Canadian studies by Craig and Noori(1986a,b) only survey small manufacturers' perception on new manufacturing technology and do not provide concrete evidence on who is using the AMTs and what are the specific attributes of the AMT users are. Thus, more survey studies to uncover the patterns and trends of AMT application in Canada are needed.

It is found that the progress of the current AMT literature follows three stages: problem discovery, missing factor identification, and measurement stages. It is

believed that most of the causes of the problem of slow AMT adoption have been identified. In fact, the inability of capital budgeting techniques to incorporate the intangible factors in the evaluation process is believed to be the major barrier. Having passed this problem discovery stage, researchers have been trying to identify the intangibles. Flexibility and strategic factors are identified as the most important intangibles that are missed out in the evaluation. Considerable amount of work has been concentrated on the measurement of these factors. Scoring model, sensitivity analysis, and lowering of hurdle rates are methods suggested in this measurement stage. The practicality of these models have not been proven. On the contrary, the problem of slow adoption continues. There seems to be a gap between the missing factor identification stage and the measurement stage.

This may suggest that we do not have a clear understanding of the underlying causes of the slow adoption problem. Although the inability to incorporate flexibility and strategic factors, and other reasons that have been mentioned, have been identified as the major causes, careful examination of how managers made AMT decisions need to be explored to provide more insights into the slow adoption problem.

Survey of AMT Adoptions

By analyzing organizations that have installed AMTs, through an examination of various information sources, some patterns and trends of AMT adoption in Canada are uncovered. First, years of adoption, applications, and locations of these AMTs are found and presented in summary forms. Second, AMTs that are used in manufacturing industries are analyzed in detail by comparing the specific attributes of these firms. These attributes include sectors of the economy, sizes of the firms, and ownership structures. Finally, patterns and trends of the Canadian AMT adoption are compared with those of the other industrialized nations to see whether Canada is lagging behind or

leading other countries in the adoption of AMTs.

AMT Decision Making Process

Through interviews with executives of the 22 firms that have adopted AMTs, data concerning their decision making processes are gathered. Careful analysis of the interview results enables the development of a general model to describe the 22 decision making processes. It is believed that this model captures most of the activities in the firms' decision making processes. Also, these decision processes fall into distinct groupings within the model. This allows us to further describe these 22 decision processes by 5 specific models according to the specific characteristics of each group in which they are called Contingency Model, Owner/Manager Model, Experienced Model, Turnkey Model, and Structural Analysis Model.

Validity of the Research Assumptions

A number of research assumptions are made by researchers in conducting studies in AMT investment decisions. Most of these are related to the justification process of the investment decision. Four important, critical, and yet controversial assumptions about the causes of slow AMT adoption are extracted from the literature and discussed in Section 4. These assumptions are: over-emphasis on the labour cost savings, underestimation of the importance of flexibility, status quo assumptions, and the inadequacy of the capital budgeting techniques. A thorough examination of the validity and rationale of these research assumptions is carried out in Section 9.

These assumptions are found to be too general in nature. Table 10.1 illustrates this point. For those 22 firms that are interviewed, there is a high deviation of the validity of the assumptions. This high deviation is due to the inter-group differences. When CAD/CAM and robot firms are investigated separately, more consistent results are found. Thus, in order to have practical significance, the

assumptions must be more specifically directed towards a particular type of technology.

TABLE 10.1: SUMMARY OF RESULTS REGARDING THE RESEARCH ASSUMPTIONS

	<u>Total*</u>	<u>CAD/CAM</u>	<u>Robot</u>
<u>Most Influential:</u>			
Labour cost savings	weak "yes"	no	yes
Other labour-related factors	no	no	no
Flexibility (F1, F4, F5)**	no	no	no
Flexibility (F2, F3)	no	yes	no
Status quo (S1, S2)	yes	yes	yes
Status quo (S3, S4)	no	no	no
<u>Usage of Capital Budgeting Techniques:</u>	8	1	5

*include two FMS firms.

** see page 4 of Appendix 4 for detailed list of the factors

(1) CAD/CAM Firms

From Table 10.1, one can see that the CAD/CAM firms do not consider labour cost savings as most influential factor in AMT investment decision. Also, capital budgeting techniques do not act as barriers to their investment since only 1 out of 10 firms uses capital budgeting techniques. Although the results indicate that 3 forms of flexibility are not considered most influential, the assumption that firms underestimate flexibility is not valid. This is because most of the firms are producing custom-made products and, therefore, "moving away from mass production of standard products to mass production of diverse products," "ability to adjust production volumes to handle unanticipated demand changes," and "reduction of inventory carryovers" are not important. However, they do consider other 2 forms, i.e. "shorter design and production time" and "accelerate the speed and reduce the cost of retooling for design changes," most influential factors. Thus, the assumption that decision makers

understate the importance of flexibility can be rejected.

However, the results for the assumption that decision makers assume business will continue as usual are mixed and no conclusion can be drawn as to the validity of this assumption.

In sum, the decision makers are "smart" enough to recognize that the real benefits of CAD/CAM comes from flexibility not labour savings and capital budgeting techniques do not act as barriers in CAD/CAM adoption. However, whether or not decision makers assume business will continue as usual is inconclusive.

(2) Robot Firms

The results of the robot firms are just in direct opposition to the CAD/CAM firms since the 3 assumptions that are found to be invalid in the CAD/CAM firms are found to be valid in the robot firms. The status quo assumption, however, is still inconclusive.

It is found that decision makers when investing in robots consider labour cost savings most influential and ignore the importance of flexibility. Also, 5 out of 10 robot firms use capital budgeting techniques and careful examination of the interview results of these firms indicate that capital budgeting techniques do act as barriers in robot adoptions.

Superficially, the results support all but the status quo assumption. However, it is found that the robots that are used in the Canadian manufacturing industries are of lower technology type (e.g. pick-and-place robots) than those discussed in the literature (e.g. sensor-based robots). Thus, the literature's criticisms may not be appropriate.

10.4 Practicality of the evaluation models

During the last three years, a number of models have been suggested by

researchers for the evaluation of AMTs. Some of these are theoretical models which are difficult for decision makers to use. Burstein and Talbi(1984), Bernard(1986), Cochran and Viswanath(1985), and Emerson(1985) are among some of these researchers.

Models suggested by Kaplan(1986) and Nelson(1984) can be considered as the two main types of model that have practical significance in overcoming the barriers of AMT justification.

Kaplan recognized the difficulty in estimating quantitative benefits for the intangibles. He, therefore, proposed, that instead of assigning arbitrary numbers for the intangibles, to calculate the NPV of the AMT investment based only on the tangible factors. If NPV is negative, management judgment will be exercised to determine whether the intangibles are worth the amount needed to turn the negative NPV to zero. If they are willing to pay for that amount, AMT investment will be made.

Kaplan's approach is good for firms that are using NPV as their evaluation method. However for many firms that have been using ROI, payback, and IRR or do not use any quantitative evaluation method, Kaplan's method is not practical. It is because the NPV method has been illustrated as the most accurate way of measuring capital investment. These firms have chosen to ignore it and use payback, ROI or IRR. It would be difficult to persuade them to use NPV -- let alone Kaplan's method of combining NPV with management judgment.

Nelson, on the other hand, proposed a scoring method. He suggested a equally-weighted scoring of 5 factors (technology, equipment, capacity, cost/benefit, and NPV) be used to select an AMT investment project among a few alternatives. He has detailed the criteria that should be used in each of these five factors.

This method is good for firms that have readily available information on those

criteria, and technically and financially competent decision makers who are involved in the evaluation process. However, many of the medium to large size firms have separate staff in the evaluation and the decision making processes for capital investments. Those that are in the evaluation group are not financially competent whereas those that are in the decision making group are not technically competent. Thus, simple capital budgeting techniques are used to provide communication between these two groups. The use of Nelson's method requires the evaluation staff to make subjective judgment in order to assign scores for each of the factors. This implies that more power will be shifted from the decision making group to the evaluation group, as the latter can assign scores arbitrarily to those factors. Therefore, Nelson's model is not suitable for medium to large size companies where the decision making group and the evaluation group are not the same.

For small companies or the owner/manager type of business, the model, with some modification, can be adopted to replace the more subjective judgment method used by the owners as Nelson has detailed many useful criteria for the evaluation of AMT. Modifications mainly include the elimination of the NPV factor since these decision makers are usually technically-oriented and lack an appreciation of complex financial procedures.

10.5 Suggestions

Apparently, there is a mismatch between what AMT offers to a firm and what procedures the firm is using to approach this AMT. Figure 10.1 illustrates this mismatch. The diagonal line can be called "equilibrium line." Any point along this line represents a perfect match between what a capital investment offers to a firm and what procedures the firm is using to approach the capital investment. For example, conventional machines offer mainly tangible benefits and have low impact on the

FIGURE 10.1 THE MISMATCH BETWEEN AMT BENEFITS AND THE CURRENT APPROACH

AB and BC represent the effect of a capital investment on the company;

AD and CD represent the actions of the company towards the capital investment

operation of the company. Therefore, the company's approach would then be the use of quantitative evaluation, and the knowledge requirement to do such an evaluation is quite narrow. On the other hand, AMTs offer mostly intangible benefits (although there may be substantial tangible benefits as well, the intangibles are more important to the company) and thus have high strategical impact on the company. Therefore, the company cannot solely rely on quantitative methods and it should place more emphasis on the qualitative evaluation. Also, a broader knowledge is needed to understand the technical, strategical, and financial implications of AMTs.

However, it has been found that companies are reluctant to move upward from the equilibrium line. Rather, they try to stay as close as possible to point A in line AD and point D in line DC. However, AMTs are closer to point B in line AB and point C in line BC. Consequently, there is a mismatch between what AMT offers and the approach used by the companies.

This mismatch can be explained by the agency theory³⁰ and the delegation of responsibilities by modern organizations. Agency problems in this context arise from conflicting interests among the decision makers and the owners of the firm. Decision makers are only interested in maximizing their own utilities -- not the utility of the owners. When the utility curve of the decision makers is different from that of the owners of the firm, decision makers will maximize their own utility at the expense of the owners'.

Since managers are rewarded according to their current performance in terms of current profitability of the firm -- not long term survival and profitability of the firm -- they make decisions to maximize short term indicators such as ROI at the expense of long term survival and profitability of the company. Guidelines and rules are set up to ensure that all the decisions conform with their utility

maximization principles. In AMT investments, decision makers are reluctant to base their decision on qualitative methods and the intangible benefits of AMTs since these will not be favourable to the current income statement. Rather, they would like to have equipment that has return on investment in one or two years time instead of AMT investment whose benefits would not be fully realized for a long period of time. Thus, to maximize their utility, they like to be as close to A in line AD as possible.

In addition to the agency problem, the separation of decision making and evaluation responsibilities contributes to the reluctance to move up to C in line DC. Although the firm may have broad knowledge, it is dispersed among different groups of staff. To achieve a compromise so that each group's power will not be eroded, firms often give up the broad knowledge that they possess and resort to the use of the narrow technical and simple financial knowledge in the evaluation.

For small companies, where the owner is the decision maker and evaluator, the above problems do not exist. However, due to the insufficient knowledge possessed by one individual, the problem of mismatch still exists.

From the insights gained from this research, a number of options can be suggested to improve the evaluation of AMTs. Also, research directions are recommended in order to ensure that the problem of slow AMT adoption receives proper attention from researchers.

Options For Potential Adopters

In order to improve the decision making process of AMT investment, this mismatch must be corrected. Based on the insights gained from the interviews, a number of practical options can be suggested to improve the evaluation process. It is hoped that this will narrow the mismatch.

The "low-tech" robots, which are used strictly as human substitutes, should

be evaluated by estimating the incremental quantitative benefits generated by the robot for longer horizons such as 10 years. An evaluation group can justify the use of a longer horizon by the flexibility of the robot in comparison to the dedicated systems.

For CAD/CAM and "hi-tech" robots, the suggested options are different for firms of different sizes:

(1) For Small Companies

Due to the lack of knowledge and evaluation procedure, it is very difficult to evaluate the investment in CAD/CAM and "hi-tech" robots. Based on this study, two options are believed to be better than the common approach of using "management gut feeling." First, Nelson's model with the elimination of the NPV factor can be implemented if sufficient information about the potential investment is available. In the case of lack of knowledge, the best option would be to hire consultants from ORC and CAD/CAM Centre to conduct a feasibility study. This recommendation is based on the favourable opinions reflected by the interviewees. They believed that they had received professional help in the evaluation stage, the implementation stage, as well as the post-implementation stage.

(2) For Medium and Large Size Companies

The use of IRR is common in many of these companies. Following Kaplan's line of thinking, an evaluation group should calculate the IRR without including factors that are believed to be non-quantifiable by the decision makers. However, if there is a consensus between the evaluation group and the decision making group that some factors such as quality can be quantified, the evaluation group should incorporate these factors in the IRR analysis. IRR is then computed on the incremental benefits generated by the tangible and near-tangible benefits.

If at this point, the computed IRR is higher than the required IRR set by the

company, there will be no problem. However, if it is lower, the evaluation group will have to work out how much per year the incremental benefits have to increase for a period of no less than 10 years to make the project's IRR equal to the required IRR. These figures can then be submitted to the decision making group. The decision makers will have to determine whether they are willing to accept a lower IRR for the benefits provided by the intangibles.

The methods suggested above are just for short term relief of the inherent bias against AMTs in the decision making process. To solve the problem of slow AMT adoption, business researchers can contribute in a number of ways.

Implications on Future Research

This study reveals a number of unexplored areas and areas that require more attention. The focus of future research for business researchers in the study of AMT adoption can be in these three areas: the understanding of the relationship between compensation scheme and decision making structure of the companies, the decision making process, and the development of specific models.

First, Barnea, Haugen, and Senbet(1981,1985) have presented convincing arguments on the relationship between management compensation and their investment perspective. They argue that current managers are more geared to the maximization of current income than long term survival and competitiveness of the firm. Therefore, they suggest that to maximize a firm's long term profit, management's compensation should be tied to the future performance of the firm. Business researchers, therefore, should explore whether management's compensation schemes have effect on the structure of the decision making process, as well as the evaluation criteria set by the decision makers. Based on these findings, an efficient contract between decision makers and the owners of the firms can be devised in such a way that decision makers are

rewarded according to their ability to increase the future profitability and the survival of the firm.

Second, the narrow focus on the evaluation stage of the decision making process as the sole cause of the problem of slow adoption must be corrected. Drawing insights gained from decision making studies by research articles such as Mintzberg, Raisinghani, and Thoret(1976), Nutt(1984) and Cray, Mallory, Butler, Hickson, and Wilson(1984), business researchers of AMT adoption can uncover the problem in different stages of the decision making process and, hopefully, the roots of the problem can be ironed out. Based on these findings, practical solutions can be suggested to cure the problem.

Finally, as we gain more knowledge about the causes of the problem of slow AMT adoption, models can be built to assist decision makers in evaluating AMTs. These models, however, should not be too general. They must be directed toward a kind of technology or technologies that have similar characteristics. Moreover, they must be designed to be used by certain type of firms.

By doing so, it is hoped that a better understanding of the decision making process of the industry will be gained and practical solutions that can be used by actual decision makers can be suggested and implemented in industry. These will help to alleviate the bias against AMTs by the traditional evaluation method and to help to quicken the pace of AMT adoption in Canada. The result will be a better foundation for the Canadian manufacturing industries to compete with aggressive foreign rivals in the increasingly volatile world markets.

FOOTNOTES

- 1 "The New Cases For Protectionism," Fortune, September 16, 1985.
- 2 The use of discounted cashflow methods started when *Capital Budgeting* written by Joel Dean and *The Theory of Investment of the Firm* by Vera and Friedrich Lutz were published in 1951. The former was written for business managers by a respected academician who did a large amount of consulting whereas the latter was written for economists interested in capital theory. These books made both academic and business managers start to think about how investments should be evaluated.
- 3 From 1981 to 1985 the United States continued to grow in importance as Canada's main trading partner; U.S.-bound exports grew from 60% to 78% of total Canadian exports. These statistics are from Exports by Countries January-December, 1985, p. 362,364, Statistics Canada.
- 4 In Bylinsky(1983), he classified FMS, CAD/CAM, and robot as advanced factory automation technologies. In Craig and Noori(1986), they classified numerical-controlled machines, robot, CAD/CAM, and FMS as Programmable Automation. Also, two technology centres were established under the Ontario Centre for Advanced Manufacturing (OCAM) which was created by the Ontario government to help Ontario companies to respond to the critical challenges of improving productivity and competing internationally. The two centres are the CAD/CAM Centre and the Robotics Centre.
- 5 A position paper offered by "Engineering and Manufacturing Advisory Council of Computer Integrated Enterprise."
- 6 The organization surveyed 257 financial officers of the largest Fortune 500 industrial firms requesting them to identify problems of implementing capital budgeting techniques. From the 102 replies, it is found that strategic considerations and risk analysis are most frequently listed problems in implementation. For further reference, please refer to Beirman(1986).
- 7 The two studies are "Robotics in the Canadian Manufacturing Industries" edited by J.A. Tanner, National Research Council, 1982 and "Strategy for Survival: The Canadian CAD/CAM Option" prepared by CAD/CAM Technology Advancement Council, September 1980.
- 8 As reported in Statistics Canada's "Inventories, Shipments, and Orders in Manufacturing Industries," Canada produced a total of \$242,862 million worth of manufacturing goods in 1985 and \$128,964 million worth were from Ontario which represents 53% of the total Canadian production.
- 9 Report On Business, p.B2, Globe & Mail, February 24, 1986.

- 10 On January 27, 1982 a document entitled "Building Ontario in the 1980's" was released by the Board of Industrial Leadership and Development (BILD), a Cabinet Committee of the Government of Ontario. The document defined long-term policy directions and investments initiatives vital to Ontario's future.
 "Technology" was one of the six major themes identified as priorities for cohesive and comprehensive development of the provincial economy. The policy document stated, "It is not for the Government to dictate to industries what they should do, but rather, to assist them where necessary to be more successful."
 In keeping with that principle, the BILD indicated that a number of new technology agencies should be formed to help Ontario companies respond to the critical challenges of improving productivity and competing internationally. As a result of the BILD initiative, the Technology Centres Act, 1982, was passed by the legislation on July 7, 1982, officially launching the Ontario Technology Centres program.
 The Ontario Centre for Advanced Manufacturing (OCAM) was established as a Crown Corporation on November 17, 1982 by a regulation to the Act and two technology centres were established under OCAM: The Ontario CAD/CAM Centre and the Ontario Robotics Centre.
- 11 *Workable Futures: Notes on Emerging Technologies* by Words Associates and Keith Newton, Economic Council of Canada, p.19, 1986.
- 12 As reported in "Europe overtakes USA," *The Industrial Robot*, Volume II, No. 1, March, 1984.
- 13 Craig and Noori (1986b) compared the possible differences in the adoption of new manufacturing technology by small and large manufacturing firms. They found that smaller firms tend to lag behind the large ones in the adoption and planning to adopt the new manufacturing technologies. According to their analysis, this is mainly due to their inability or lack of time to gather first-hand knowledge about automation and the high capital cost of the equipment.
- 14 Nine firms are found to be Canadian-owned and four Canadian-controlled using Statistics Canada's Inter-Corporate Ownership. Since twelve firms are not found in that list, it is very likely that they are small Canadian-owned companies that are not listed in that document.
- 15 Figure for 1984 is available from the Japan Industrial Robot Association but are not used since Japanese definition of robots is very loose and gives a misleadingly large lead over other countries. For example, more than one-third of the robots produced in Japan in 1984 were simple pick-and-place machines that have to be reset by human workers. Fewer than half were variable-sequence and playback robots capable of switching tasks easily. Only one-tenth was classified as "Intelligent."
- 16 "Industrial Survival Tied To Automation," by Ronald Anderson, *Globe & Mail*, April 18, 1986, p.B2.

- 17 "Robotics Needed In More Sectors," by Ronald Anderson, *Globe & Mail*, September 18, 1986, p.B2.
- 18 *Workable Futures: Notes on Emerging Technologies* by Words Associates and Keith Newton, Economic Council of Canada, p.19, 1986.
- 19 Extracted from the "86' Hi-tech Census of CAD/CAM Installations" published by the Canadian Machinery and Metalworking in May, 1986.
- 20 The Association has surveyed 7000 of its member in February, 1982
- 21 A speech of the Ontario Industry and Trade Minister Frank Miller to the members of the Canadian Manufacturers' Association in 1984.
- 22 "Domtex modernizes" *Financial Post*, April 20, 1985
- 23 This is quoted by Stauffer(1983) in *Robotics Today*, Volume 5, No. 2, p. 37.
- 24 The decision rule is:
if $|t^*| \leq t(1-\alpha/2; n-2)$; do not reject H_0
if $|t^*| > t(1-\alpha/2; n-2)$; reject H_0
- 25 The results of the study is reported in Schmenner(1983).
- 26 "The Justification and Acquisition of New Technology," 1986 Annual Conference, Graduate School of Management, University of Rochester, New York, September 18-19, 1986.
- 27 *ibid.*, Lederer, Phillip J. "Organizational Economics, Cost Accounting and the Justification of New Technologies."
- 28 Internal validity can be defined as the degree to which the results of the study can be relied upon as being correct. Stated in another fashion, internal validity is strongest when alternative interpretations of the study's results are ruled out.
- 29 External validity can be defined as the degree to which the study's results can be generalized across populations, settings, and other, similar conditions.
- 30 A detail discussion of the agency theory can be found in Barnea, Haugen, and Senbet(1981,1985).

APPENDIX 1: DEFINITIONS OF ADVANCED MANUFACTURING TECHNOLOGIES

The following descriptions might be helpful to clarify the meaning of the three technologies used in this study:

Robot: is a programmable multifunctional manipulator designed to move materials, parts, or specialized devices through various programmable motions for the performance of a variety tasks.

Computer-Aided Design (CAD): is any design activity that involves the effective use of the computer to create or modify an engineering design.

Computer-Aided Manufacturing (CAM): is the effective utilization of computer technology in the management, control, and operations of the manufacturing facility through either direct or indirect computer interface with the physical and human resources of the company.

Flexible Manufacturing Systems (FMS): are integrated systems of computers, numerical-controlled machine tools, inspection units, and some automated material handling devices such as shuttle pallets, carts(robot carriers) and industrial robots. The raw parts are manually loaded and unloaded at a central load/unload station. Real-time computer control system moves the carts with the fixtures and the parts to the required workstation for processing. Upon completion, the part is transferred by a cart to next required work station, to the load/unload station, or to the buffer area (pallet stocker) where it queues temporarily.

APPENDIX 2: PROJECT EVALUATION TECHNIQUES

1. Subjective numeric models

The subjective numeric models use a number of criteria to evaluate a project. They are designed to overcome some of the disadvantages of the objective numeric models, particularly they focus on a single decision criterion. Some common forms of subjective numeric models are discussed below:

(1) Unweighted 0-1 factor model

The management selects a set of relevant factors that are crucial to evaluation of the project. These factors are then scored by one or more raters. The raters should have a clear understanding of organizational goals and a good knowledge of the firm's potential project portfolio. A score of 1 will be given if a particular factor qualifies from the rater's opinion, zero will be given otherwise.

A benchmark score, for example, at least 50% of the factors must have a score of 1. If the project's score passes the benchmark, it will be accepted; otherwise, it will be rejected.

The main advantage of such a model is that it uses several criteria in the decision process. The major disadvantages are that it assumes all criteria of equal importance, and it allows for no gradation of the degree to which a specific project meets the various criteria.

(2) Unweighted factor scoring model

The second disadvantage of the unweighted 0-1 factor model can be overcome by using a linear scale to which the project being evaluated meets each of the crucial factors. For example, for each factor, a scale of 1 to 10 can be used. The scores of each factor can then be summed up, and those projects, that have a score above the

benchmark score are selected.

Although this method uses multiple criteria and overcomes the lack of gradation of the degree at which a specific project meets the various criteria, it still assumes all criteria are of equal importance.

(3) Weighted Factor Scoring Model

This model is designed to overcome the disadvantage of the unweighted model. Each factor is given a weight, usually as a percentage of the total weight. The score given to each factor is then multiplied by the weight to obtain a weighted score. The weighted score of each factor is cumulated to give a grand weighted score. If this score passes the benchmark score, the project will be accepted.

These three subjective numeric models can also be used to select one or more projects from a number of alternatives.

2. Objective numeric scoring methods

A capital budgeting analysis is used to determine whether the benefits stemming from investments in a real asset (such as plant and equipment) are worth more than the cost involved in acquiring the asset. Traditionally, capital budgeting can be used to evaluate both asset replacement and new asset acquisition decisions. Although theoretical reasoning clearly indicates that the proper treatment of capital budgeting decision should be based on the Net Present Value (NPV) of the project, in practice several methods are used, especially the Internal Rate of Return (IRR) and payback period. Therefore, the characteristics and pitfalls of each of the five commonly used methods are discussed below.

(1) Payback period

The payback period for a project is the original investment divided by the

estimated annual cash inflows from the project. The resulted ratio is the number of years required for the project to repay its original investment. The main advantage of the payback method is its extreme simplicity. If the original investment can be recovered in a benchmark payback period, the project will be accepted.

However, this method ignores the time value of money, inflation, and the risk characteristics of the cash flows. Also, it ignores all subsequent cash flows after the payback period. The result leads to a bias against projects that have their cash inflows many years after the initial investment.

(2) Average Rate of Return (Return on Investment)

It is the ratio of the average annual profit to the original investment in the project. The average annual profit is computed by taking the average of the accounting profit for the estimated life of the project. In addition to ignoring the order of cash flow, subsequently the opportunity cost of capital, this method uses the book value of the profit and asset figure which can be different for an identical project using different accounting treatments. A common practice in industry is to compute the ROI of the first complete year of use. This ROI will tend to understate the actual return on investment, creating a bias against accepting investments that should be accepted.

(3) Net Present Value method

The NPV requires the estimation of expected future net cash flows and the opportunity cost of capital which composes of the real interest rate, inflation premium and risk premium. The opportunity cost of capital can be estimated using the Capital Asset Pricing Model. Once the periodic net cash flows (CFs) and the cost of capital, r , are estimated, present value of the project is computed by discounting the cash flows at the rate r . The NPV is then obtained by subtracting the original investment, OI , from

the present value:

$$NPV = \sum CF_t(1+r)^{-t} - OI \quad (\text{where } t \text{ is the cash flow periods})$$

If NPV is greater than zero, the project will be accepted; otherwise, the project will be rejected.

If the periodic cash flows and opportunity cost of capital are correctly estimated, NPV is superior than any of the above measures since it takes time value of money, risk characteristic of the cash flows, and inflation premium into consideration. However, periodic cash flow is difficult to estimate when the projects are new to the industry and no past data can be used. In addition, if the project requires substantial amount of investment, the firm's risk characteristics will be changed and the cost of capital becomes difficult to estimate.

(4) Internal Rate of Return method

IRR is the discount rate which makes NPV equal to zero. When the periodic cash flow is estimated, IRR can be obtained through trial and error until NPV is equal to zero. The project is accepted if IRR is greater than the opportunity cost of capital that the firm required.

The only advantage of using IRR over NPV may be because managers have notions about what the opportunity cost of capital is and feel more comfortable in comparing the IRR with their subjective evaluation of the opportunity cost of capital. However, the IRR suffers from four major pitfalls:

i) The rule applies only if the project generates negative cash flows followed by positive ones. If this order is reversed, the decision rule should be reversed: projects with an IRR less than r should be accepted, while those with an IRR greater than r should be rejected;

ii) if there is more than one change in the sign of cash flows, then there could be multiple IRR or no IRR at all;

iii) unlike NPVs, IRRs do not add. Hence, when comparing mutually exclusive projects, comparing IRRs does not make sense, whereas comparing NPVs is still correct; and

iv) when using the IRR, the discount rate is assumed to be constant over the economic life of the project. For example, the cost of capital for the later part of the project is lower since a lot of uncertainties are eliminated; thus, different cost of capital should be used. Unfortunately, IRR assumes constant rate whereas NPV calculation can easily account for this by using different discount rates for different cash flows.

(5) Profitability Index

The profitability index (or benefit-cost ratio) is the present value of forecasted future cash flows divided by the original investment. The profitability index rule tells us to accept all projects with an index greater than 1. If the profitability index is greater than 1, the present value is greater than the original investment and so the project must have a positive NPV. The Profitability Index, therefore, leads to exactly the same decisions as NPV.

The major pitfall of this method is that comparing the indices is not suitable for comparing projects. Since the computations needed to obtain the index are exactly the same as those for the NPV, it is not necessary to use this method.

To have a more in-depth understanding of the characteristics, advantages, and pitfalls of these capital budgeting techniques, one can refer to Brealey(1984), Clark, Hindelang, and Pritchard(1984), and Bierman(1986).

APPENDIX 3: SOURCE OF DATA FOR SURVEY OF AMT ADOPTION

<u>Source</u>	<u>No. of Firms</u>	<u>Criteria</u>	<u>Useful Information</u>
Blue Book of Canadian Business	117	Major Firms	In-depth profiles (who they are, what they do, how they grew and developed, how they perform, and their roles in Canada's economy and society).
	500	Revenue > \$10m or Asset > \$5m or employee > 500	Rankings of the top 500 firms operating in Canada by Sales, assets, net income.
	4000	same as above	company location, ownership and legal structure, indicators of relative size, nature of business, contact person.
Canadian Facts Figures	n/a	n/a	Selected statistics from various and sources. Useful information include: productivity figures, foreign ownership in Canada.
Canadian Key Business Index	7800	employee > 1000 or net worth > \$1.5m or sales > \$25m	Size characteristics: amount of sales, number of employees. List of officers and managers.
	Approx. 7000	employee 100-999 or net worth \$.75m-\$1.5m or sales \$10m-\$25m	same as above.
Canadian Trade Index	Almost all	n/a	sales, company size, nature of business, contact persons.
Dept. of Consumer & Corporate Affairs Financial Statements Microfiche	n/a	corporations with assets > \$5m and revenue > \$10m	audited federal financial statements
Report on Business	n/a	n/a	Aggregate data of each type of manufacturing under the SIC code.
Scott's Directories	Almost all	n/a	A cross index referencing the SIC code numbers of each firm to the Statcan codes; Grouping of same SIC number firms together.

APPENDIX 4: REQUEST LETTER(2 PAGES)

- The appendix depicts the letter that is sent to firms with CAD/CAM installations. The letters that are sent to firms with Robot and FMS installations are the same except that the term "CAD/CAM" are replaced by the terms "Robots" or "FMS" in the letter respectively.

October 26, 1986

COMPANY NAME
COMPANY ADDRESS
Attn: Receiver and Title

Dear _____:

Re: Research on Computer-Aided Design and Manufacturing (CAD/CAM)

The Manufacturing Systems Centre affiliated with the School of Business at Carleton University is conducting a study on the decision making process of investment in Computer Aided Design and Manufacturing. The focus of this study is on the economic justification of the investment in such advanced manufacturing technologies.

We are interested in learning about the decision making process which was used when evaluating the investment in CAD/CAM. We understand that your company is one of the first in Canada to have adopted this new manufacturing technology. Thus, we would like to request your participation in this study. To show our gratitude for your assistance, we shall be pleased to send you a summary report of insights gained from the research.

Very shortly Mr. Steve Loo, one of our graduate students and research associate of the Manufacturing Systems Centre, will be in touch with you to arrange an interview. The interview will not last for more than an hour. Information gathered from the interviews will be aggregated and no information on individual organizations or people involved will be divulged. A brief summary of the type of information that we would like to obtain during our interview is enclosed for your perusal.

I shall appreciate your assistance as your help is essential to the study's success.

Sincerely,

A. J. Bailetti, Director
School of Business

DESCRIPTION OF THE INTERVIEW

We would like to cover the following areas in our interview:

1. General

- general company information such as sales, number of employees, types of production, etc.

2. Reasons For the CAD/CAM investment

- main reasons for investing in CAD/CAM.
- importance of these factors: labour saving, flexibility, market share and competitiveness in justifying CAD/CAM investment.

3. Investment Decision Making Process

- the process that your CAD/CAM investment has gone through from the first mention of the issue by someone in your company until the final decision was made.

4. Evaluation Process

- detailed description of the methods used in the pre-acquisition evaluation of the CAD/CAM.
- strengths and weaknesses of the methods used.
- the role of capital budgeting techniques in the evaluative process.

APPENDIX 5: INTERVIEW QUESTIONNAIRE (5 PAGES)

- The questionnaire consists of 5 pages. Answers to the first three pages are for qualitative analysis whereas the last two pages are for quantitative analysis.
- The appendix depicts the questionnaire that is used to interview executives of the firms with CAD/CAM installations. The questionnaires that are used to interview executives of the firms with robot and FMS installations are the same except that the term "CAD/CAM" are replaced by the terms "Robots" or "FMS" respectively in the Definition section of the questionnaire.

Proposed Interview Questions

Definition

AMTs stand for Advanced Manufacturing Technologies. CAD/CAM can be considered as a type of AMTs. Thus, the term "AMT" in the following questions is used to denote CAD/CAM.

Purpose of this interview:

To understand how the AMT decision was made.

1. General

- 1.1 Could you tell me a bit about your firm ? How big you are, what kind of production process you use and etc ?
- 1.2 How many employees do you have ?
- 1.3 What was your last fiscal year's gross sales?
- 1.4 Are you a public company ?
- 1.5 Are you a subsidiary of another company ?
- 1.6 How could you describe your production process ? Are you producing standard products or customized products ?
- 1.7 Do you engage in any operations other than manufacturing ?
- 1.8 Which suppliers provide you with raw materials ? Are they dependable in terms of price, quality, quantity, and service?
- 1.9 What kind of customers do you have? Are they dependable ?
- 1.10 Do you have a labour union ?
- 1.11 How would you characterize your relationship with the labour(or labour union) ?
- 1.12 What advantages do your products have over your competitors's product?

2. AMT Investment Information

- 2.0 Could you describe how your robot is used ? Do you satisfy with its performance?
- 2.1 Could you describe the decision making process for the AMT investment ?
- 2.2 How did it start ?

- 2.3 What was the main sequence of events ? (i.e. process that has gone through from the first mention of the issue by someone in your firm until the final decision was made.)
- 2.4 When was the decision to invest in AMT made ?
- 2.5 How much did the AMT cost?
- 2.6 Who are in the decision making group to purchase this AMT?
- 2.7 In what way was this decision made different from other machinery acquisition decision ?

3. Reasons Of This Investment

- 3.1 What were the main reasons for investing in AMT ?
- 3.2 a) Why labour-related factors are the most important reasons in justifying for AMT ?
or
b) Why labour-related factors are not the most important reasons in justifying AMT ?
- 3.3 a) Why production flexibility is so important to your company ? If the supply of raw materials and demand for your goods are more dependable, will production flexibility be less important ?
or
b) Why production flexibility is not so important to your company ? If the supply of raw materials and demand for your goods are less dependable, will production flexibility be less important ?
- 3.4 Will the AMT enhance your ability to produce more variety of products ?
- 3.5 If so, how important is this characteristic at the time of pre-acquisition evaluation ?
- 3.6 At the time you purchase this AMT, has anybody in a similar industry like yours already acquired a similar type of machine ?
- 3.7 If the answer to 3.6 is yes,
 - a) Had you been able to study the performance of the machine owned by your competitor before you acquired your own system ?
 - b) Did those firms that had acquired AMT posed a threat to your market share ?

4. Evaluation Process

- 4.1 Can you describe the type(s) of method used in the pre-acquisition evaluation of the AMT ?
- 4.2 Do you use capital budgeting techniques ?

If capital budgeting (discounted cashflow) method is used. (Q4.3-Q4.8)

- 4.3 Do the capital budgeting techniques always give you the right answer?
- 4.4 Do you have any unique problems with capital budgeting technique when it was used in evaluating the AMT investment ?
- 4.5 Since flexible automation has a lot of intangible benefits such as higher flexibility and better quality, do you feel that capital budgeting technique is adequate to the evaluation job ?
- 4.6 How did you estimate the incremental savings generated by the investment ?
- 4.7 What would have happened if you did not invest in AMT ?
- 4.8 Did you use a single discount rate for that investment ? If this is true, is this the hurdle rate that used to measure all capital investments?

If capital budgeting technique is not used. (Q4.9-Q4.11)

- 4.9 Why not?
- 4.10 What are the advantages of your techniques over the capital budgeting techniques ?
- 4.11 Do your techniques always give you the correct answer ?

POSSIBLE REASONS FOR INVESTING IN ROBOTS:Not
influential
at allNot very
influential

Neutral

Very
InfluentialMost
Influential**Labour-related:**

1. Increasing cost of labour
2. Declining productivity of employees
3. Lack of skilled labours
4. Employees unwilling to perform certain jobs
5. Eliminate hazardous job
6. Eliminate repetitive job
7. Reduction of labour-cost

Flexibility-related:

1. Move away from mass production of standard products to mass production of diverse products
2. Shorter design and production time
3. Accelerate the speed and reduces cost of retooling for design changes
4. Ability to adjust production volumes to handle unanticipated demand changes
5. Reduction of inventory carryovers

Others (Status quo assumption-related):

1. Concern over product quality
2. Belief in the importance of flexible automation by top management
3. A concern over the loss of market share to competition
4. A concern that the competition are automating

Reasons For Investing In AMT:

Labour-related factors

Flexibility-related factors

Others (please specify)

1 _____

2 _____

3 _____

TOTAL**100%**

of/de

3

MICRO

APPENDIX 6: SUMMARY DATA FOR CAD/CAM FIRMS

<u>SAMPLE</u>	<u>COUNTRY</u>	<u>TYPE OF OWNERSHIP</u>	<u>LOCATION</u>	<u>SALE (\$M)</u>	<u>% OF FOREIGN SALES</u>	<u>EMPLOYEE</u>
1	Canada	Owner/Mgr	Toronto	1-5	30	18
2	U.S.	Individual	Toronto	10	N/A	120
3	N/A	N/A	Mississauga	N/A	N/A	51
4	Canada	Partners	Waterloo	5	6	100
5	Canada	Public	Kitchener	20	N/A	160
6	Canada	Family	Toronto	100	35	800
7	Canada	Family	Scarborough	2	N/A	45
8	U.S.	Family	Scarborough	8	75	115
9	Canada	Public	Ottawa	50	70	600
10	Canada	Owner/Mgr	Ottawa	2	N/A	50

	<u>PRODUCT TYPE</u>	<u>PRODUCTION METHOD</u>	<u>TYPE OF CUSTOMERS</u>	<u>COST (\$000)</u>	<u>ADOPTION YEAR</u>	<u>UNION STATUS</u>	<u>RELATIONSHIP WITH LABOUR</u>
1	Plastic	Custom	Industrial	350	85	No	Very Good
2	Sheet Metal Fabrication	Custom	Industrial	1265	83	Yes	Fair
3	Mold Making	Custom	Industrial	150	84	N/A	N/A
4	Steel Parts	Custom	Industrial	140	83	No	Good
5	Military	Standard	Government	280	81	No	Good
6	Fabricating	Standard	Industrial	750	84	No	Very Good
7	Steel Parts	Custom	Industrial	1200	82	No	Very Good
8	Bladding	Custom	Industrial	41	86	No	Good
9	Computer Communication	Custom	Diverse	500	83	N/A	N/A
10	Steel Parts	Custom	Industrial	N/A	81	No	Good

APPENDIX 7: SUMMARY DATA FOR ROBOTIC FIRMS

<u>SAMPLE</u>	<u>COUNTRY</u>	<u>TYPE OF OWNERSHIP</u>	<u>LOCATION</u>	<u>SALE (\$M)</u>	<u>% OF FOREIGN SALES</u>	<u>EMPLOYEE</u>
1	Scotland/ Switzerland	Joint Venture	Scarborough	44	25	300
2	Canada/ Germany	Joint Venture	Mississauga	6	20	60
3	Canada	Subsidiary	Hamilton	200	20	200
4	Canada	Owner/Mgr	Toronto	N/A	N/A	45
5	U.S.	Subsidiary	Hamilton	578	50	2500
6	U.S.	Subsidiary	Hamilton	961	N/A	500
7	U.S.	Subsidiary	Rexdale	50	N/A	150
8	U.S.	Subsidiary	Port Hope	N/A	N/A	250
9	U.S.	Subsidiary	Woodstock	50	95	400
10	U.S.	Subsidiary	Oshawa	18993	N/A	70000

	<u>PRODUCT TYPE</u>	<u>PRODUCTION METHOD</u>	<u>TYPE OF CUSTOMERS</u>	<u>COST (\$000)</u>	<u>ADOPTION YEAR</u>	<u>UNION STATUS</u>	<u>RELATIONSHIP WITH LABOUR</u>
1	Turbines	Custom	Ont. Hydro	4000	86	N/A	N/A
2	Shopping Carts	Standard	Major Supermarkets	150	84	Yes	Bad
3	Railcar	Custom	CN, CP	440	86	Yes	Bad
4	N/A	Custom	N/A	50	80	No	Very Good
5	Turbines	Custom	Electricity Stations	504	84	Yes	Very Good
6	Agriculture Equipments	Standard	Farmers	600	80	Yes	Bad
7	Brakes	Standard	Auto Co.	380	85	Yes	Bad
8	Material Handling Equipments	Custom	Warehouses	123	86	Yes	N/A
9	Disc brakes	Standard	Auto Co.	2800	79	N/A	Very Good
10	Automobiles	Standard	Consumer	N/A	79	Yes	Good

APPENDIX 8: CUMMULATIVE BINOMIAL PROBABILITES

TABLE A8.1: NUMBER OF FIRMS REPORTED THAT THE FACTORS ARE MOST INFLUENTIAL

<u>FACTORS</u>	<u>TOTAL</u>	<u>CAD/CAM</u>	<u>ROBOT</u>
L1	2	0	1
L2	0	0	0
L3	3	2	1
L4	1	0	1
L5	0	0	0
L6	1	0	1
L7	7	1	5
F1	3	2	0
F2	6	5	0
F3	5	3	1
F4	3	2	0
F5	3	2	0
S1	9	4	4
S2	9	3	4
S3	3	0	1
S4	3	0	1

TABLE A8.3: BINOMIAL PROBABILITIES OF LABOUR-RELATED FACTORS IN CAD/CAM SUBSAMPLE

$X \geq X_i$	<u>L1</u> $p=0/10$	<u>L2</u> $p=0/10$	<u>L3</u> $p=2/10$	<u>L4</u> $p=0/10$	<u>L5</u> $p=0/10$	<u>L6</u> $p=0/10$	<u>L7</u> $p=1/10$
$X_1 = 10$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$X_2 \geq 9$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$X_3 \geq 8$	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
$X_4 \geq 7$	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000
$X_5 \geq 6$	0.0000	0.0000	0.0064	0.0000	0.0000	0.0000	0.0001
$X_6 \geq 5$	0.0000	0.0000	0.0328	0.0000	0.0000	0.0000	0.0016
$X_7 \geq 4$	0.0000	0.0000	0.1209	0.0000	0.0000	0.0000	0.0128
$X_8 \geq 3$	0.0000	0.0000	0.3222	0.0000	0.0000	0.0000	0.0702
$X_9 \geq 2$	0.0000	0.0000	0.6242	0.0000	0.0000	0.0000	0.2639
$X_{10} \geq 1$	0.0000	0.0000	0.8926	0.0000	0.0000	0.0000	0.6513
$X_{11} \geq 0$	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	1.0000

TABLE A8.4: BINOMIAL PROBABILITIES OF LABOUR-RELATED FACTORS IN ROBOT SUBSAMPLE

$X \geq X_i$	<u>L1</u> $p=1/10$	<u>L2</u> $p=0/10$	<u>L3</u> $p=1/10$	<u>L4</u> $p=1/10$	<u>L5</u> $p=0/10$	<u>L6</u> $p=1/10$	<u>L7</u> $p=5/10$
$X_1 = 10$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010
$X_2 \geq 9$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0107
$X_3 \geq 8$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0547
$X_4 \geq 7$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1719
$X_5 \geq 6$	0.0001	0.0000	0.0001	0.0001	0.0000	0.0001	0.3770
$X_6 \geq 5$	0.0016	0.0000	0.0016	0.0016	0.0000	0.0016	0.6230
$X_7 \geq 4$	0.0128	0.0000	0.0128	0.0128	0.0000	0.0128	0.8280
$X_8 \geq 3$	0.0702	0.0000	0.0702	0.0702	0.0000	0.0702	0.9453
$X_9 \geq 2$	0.2639	0.0000	0.2639	0.2639	0.0000	0.2639	0.9893
$X_{10} \geq 1$	0.6513	0.0000	0.6513	0.6513	0.0000	0.6513	0.9990
$X_{11} \geq 0$	1.0000	0.0000	1.0000	1.0000	0.0000	1.0000	1.0000

APPENDIX 9: DISCOUNTED CASH FLOW METHODS EMPLOYED BY THREE COMPANIES:

- 1) TABLE A9.1: NPV AND IRR USED BY AN ELECTRICAL COMPANY**
- 2) TABLE A9.2: IRR WITH SENSITIVITY ANALYSIS BY AN AUTO PARTS SUPPLIERS**
- 3) TABLE A9.3: STANDARD FORM USED BY A MATERIAL HANDLING MACHINE PRODUCER**

TABLE A9.1: NPV AND IRR USED BY AN ELECTRICAL COMPANY

PROJECT A9-12									
Form 1002 (3-81)									
STATE: ASSET EVALUATION SHEET									
(Numbers in Thousands)									
Date: 12-80									
Line	Description of Expenditures	Prior to 1981	Total 1981 Project	(1)	(2)	(3)	(4)	(5)	(6)
1	Depreciation Non-Recurring Project	0	40	40	20	0	0	0	0
2	Manufacturing Non-Recurring Strategic	0	0	0	0	0	0	0	0
3	Engineering Non-Recurring Strategic	0	0	0	0	0	0	0	0
4	Marketing Non-Recurring Strategic	0	0	0	0	0	0	0	0
5	Administration Non-Recurring Strategic	0	0	0	0	0	0	0	0
6	Other	0	0	0	0	0	0	0	0
7		0	0	0	0	0	0	0	0
8		0	0	0	0	0	0	0	0
9	Total Div. Strategic Expense (Sum L1..8)	0	40	40	20	0	0	0	0
10	Land	0	0	0	0	0	0	0	0
11	Building	0	0	0	0	0	0	0	0
12	Machinery & Equipment	0	500	500	120	0	0	0	0
13	Debttable Asset And Other (Specify)	0	0	0	0	0	0	0	0
14	Less Salvage Value Present Equipment	0	0	0	0	0	0	0	0
15	Government Grants/Investment Tax Credit	0	0	0	0	0	0	0	0
16	Net Capital Expenditure (Sum L10..15) Less L16..L15)	0	500	500	120	0	0	0	0
17	Additional Accounts Receivables	0	0	0	0	0	0	0	0
18	Increase Inventory Acquire	0	0	0	0	0	0	0	0
19	Other (Specify)	0	0	0	0	0	0	0	0
20	Less Trade Payables Or Product Guarantee	0	0	0	0	0	0	0	0
21	Net Working Capital (Sum L17..19 Less 20)	0	0	0	0	0	0	0	0
22	Purchase Price Of Being Business	0	0	0	0	0	0	0	0
23	Cash Flow-Expenditures (Sum L9,16,21,22)	0	540	420	140	0	0	0	0

TABLE A9.1: NPV AND IRR USED BY AN ELECTRICAL COMPANY (Cont'd)

Line No.	Description of Receipts	Year									
		1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
24	Incremental Sales Billied	0	0	0	0	0	0	0	0	0	0
25	Incremental I.A.T. before Dep.	0	0	0	0	0	0	0	0	0	0
26	Net Cost Improvement before Dep.	0	2192	53	184	197	207	222	235	249	264
27	Income before Taxes before Dep. (L25+L26)	0	2192	53	184	197	209	222	235	249	264
28	Federal Income Taxes (Tax Rate x L27)	0	975	24	83	88	93	99	105	111	117
29	Strategic Expense Tax Adj (Tax Rate x L9)	0	27	18	9	0	0	0	0	0	0
30	Net Depreciation Tax Adjustment	0	196	17	34	34	27	22	18	14	11
31	Net. Of Working Cap. And/Or Terminal Value	0	0	0	0	0	0	0	0	0	0
32	Cash Flow Receipts (Sum L27+L29..31 less L30)	0	1359	64	148	144	143	143	148	152	158
33	Net Cash Flow (L31 less L23)	0	875	-346	0	144	143	143	148	152	158
34	Net S.L. Improv./Amortization	447	19	44	50	50	50	50	50	50	50
35	Net Present I.A.T. (1-(1+Rate) ^{-L27} /(Rate))	974	-5	67	81	88	93	99	105	111	117
36	Net Cash Flow (L31 less L34)	447	19	44	50	50	50	50	50	50	50
37	Net Present I.A.T. (1-(1+Rate) ^{-L36} /(Rate))	245	440	370	346	289	239	188	138	88	37
38	Net Present NPV (L36/L37 x 100)	-0.9	15.3	20.9	23.9	27.9	32.9	38.3	45.1	52.3	60.7
39	Net Total I.A.T. Of Project Line-S.L. Basis	447	19	44	50	50	50	50	50	50	50
40	Net EPS (Acquisition) Shares	447	19	44	50	50	50	50	50	50	50
41	Net Present Of Sales Billied	447	19	44	50	50	50	50	50	50	50
42	Net Present NPV	447	19	44	50	50	50	50	50	50	50
43	NET RATE OF RETURN	28.3									
44	INCLUDING TERMINAL VALUE	28.6									
45	CASH FLOW INCLUDING I.V.	964	-346	0	144	143	143	148	152	158	164

TABLE A9.3: STANDARD FORM USED BY A MATERIAL HANDLING
MACHINE PRODUCER

Project No. _____

MAP SUMMARY FORM

(AVERAGING SHORT CUT)

PROJECT Robotic Arc Welding Cell

ALTERNATIVE _____

COMPARISON PERIOD (years) _____

(P) 1 yr.

ASSUMED OPERATING RATE OF PROJECT (hours per year) _____

4160

I. OPERATING ADVANTAGE

(NEXT YEAR For A 1 Year Comparison Period, * ANNUAL AVERAGES For Longer Periods)

A. EFFECT OF PROJECT ON REVENUE

	INCREASE	DECREASE
1 From change in quality of products	\$ --	\$ --
2 From change in volume of output	--	--
3 TOTAL	\$ -- X \$ --	Y

B. EFFECT ON OPERATING COSTS

4 Direct Labor <u>4050 hrs/yr @ \$8.29/hr</u>	\$ --	\$ 33,575
5 Indirect Labor	--	--
6 Fringe Benefits	--	8,394
7 Maintenance	--	--
8 Tooling	--	--
9 Materials and Supplies	--	540
10 Inspection	--	--
11 Assembly	--	--
12 Scrap and Rework	--	--
13 Down Time	--	--
14 Power	--	--
15 Floor Space	--	--
16 Property Taxes and Insurance	529	--
17 SubContracting	--	--
18 Inventory	--	--
19 Safety	--	--
20 Flexibility	--	1,200
21 Other	--	1,800
22 TOTAL	\$ 529 Y \$	45,509 X

C. COMBINED EFFECT

23 Net Increase in Revenue	(3X - 3Y)	\$ --
24 Net Decrease in Operating Costs	(22X - 22Y)	\$ 44,980
25 ANNUAL OPERATING ADVANTAGE	(23 + 24)	\$ 44,980

*Next year means the first year of project operation. For projects with a significant break-in period, use performance after break-in.

TABLE A9.3: STANDARD FORM USED BY A MATERIAL HANDLING MACHINE PRODUCER (cont'd)

II INVESTMENT AND RETURN

A INITIAL INVESTMENT

26	Installed Cost of Project	\$ 123,312		
	Minus Initial Tax Benefit Of	\$ 15,931	(Net Cost)	\$ 107,381
27	Investment In Alternative Capital Additions			
	Minus Initial Tax Benefit	\$ --		
	Plus Disposal Value of Assets Retired By Project	\$ --		\$ --
28	INITIAL NET INVESTMENT (26-27)			<u>\$ 107,381</u>

B TERMINAL INVESTMENT

29 Retention Value of Project at End of Comparison Period

(Estimate For Assets Which Cannot Be Liquidated Or Expensed For Others Estimate On Use M A P I Charts)

Item or Group	Installed Cost, Minus Initial Tax Benefit (Net Cost) A	Service Life (Years) B	Disposal Value, End of Life (Percent of Net Cost) C	M A P I Chart Number D	Chart Percentage E	Retention Value (A x E) F
Robotic Arc Welding Cell	\$ 107,381	9	10%	2A	82%	\$ 88,052

	Estimated From Charts (Total Of Col F)	\$ 88,052	
	Plus Otherwise Estimated	\$ --	\$ 88,052
30	Disposal Value Of Alternative At End Of Period*		\$ --
31	TERMINAL NET INVESTMENT (29-30)		<u>\$ 88,052</u>

C RETURN

32	Average Net Capital Consumption $(\frac{N_1 - N_2}{T})$	\$ 19,329
33	Average Net Investment $(\frac{N_1 + N_2}{2})$	\$ 97,217
34	BEFORE-TAX RETURN $(\frac{N_1 - N_2}{N_1 + N_2} \times 100)$	% 20
35	Increase In Depreciation And Interest Deductions	\$ 32,997
36	Taxable Operating Advantage (25-35)	\$ 11,903
37	Increase In Income Tax $(36 \times \text{Tax Rate})$ 52%	\$ 6,231
38	After Tax Operating Advantage (25-37)	\$ 38,799
39	Available For Return On Investment (38-32)	\$ 19,420
40	AFTER-TAX RETURN $(\frac{N_1 - N_2}{N_1 + N_2} \times 100)$	% 20

*Adjust for tax adjustments

(Adapted from Machinery and Allied Products)

Prepared By _____ Div Controller _____
 Approved By Pl Supt _____ Mfg Eng _____
 Div Pres / Mgr _____ Date _____

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