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Management Accounting And The Adoption Of Flexible Automation

Anton Peter Dimnik

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MANAGEMENT ACCOUNTING AND THE ADOPTION OF FLEXIBLE AUTOMATION

by

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School of Business Administration

Submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Graduate Studies
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LIST OF FIGURES

ABSTRACT

There is a widely held, but little tested, supposition that certain characteristics and uses of management accounting and control systems are retarding the adoption of flexible automation technologies such as robots and other computer controlled machines. This thesis describes an empirical study of the relationships between adoption of flexible automation and those aspects of accounting systems most often cited as inhibiting adoption: emphasis on accounting measures in managerial evaluation, length of time horizons of evaluations and capital budgeting criteria, emphasis on financial criteria in justifying capital investments, and inability of accounting systems to capture costs and benefits of automation. As well, by using partial correlations, the study examines the relationships between accounting and adoption variables with decentralization held constant. Data were collected with a mail questionnaire survey of 32 managers of plants supplying parts to General Motors of Canada. In addition, 29 of the managers were personally interviewed. A statistical analysis indicates that the long-term time horizon of budget targets and reports is the only accounting variable significantly correlated with adoption, and that decentralization does not impact on the adoption-accounting relationships. The statistical results are interpreted in the light of information gleaned from the face-to-face interviews and plant visits. After presenting an agenda for future research and arguing the need for more field research, the thesis concludes with the recommendation that top management wishing to promote the adoption of advanced technologies lengthen the time horizons of budget targets and reports.

ACKNOWLEDGEMENTS

It is not often that we are given a chance to publicly thank those who have helped us, so I will take full advantage of this opportunity.

I thank the Faculty of Administration at the University of Regina, especially Dean Hutchings for first suggesting doctoral studies, and Professors Hopkins, McLaren and Beshara for encouraging me and preparing me for graduate school.

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One of the best decisions I ever made was to study with the MACS area group at Western. I have never met a more supportive group of people. I thank Ross Archibald for his leadership; Claude Lanfranconi for his good counsel, enthusiasm and encouragement; Rich Mimick for his friendliness; and Rick Robertson and Howard Teal, for showing the way. I am also grateful to Julien Bilodeau, my partner in the PhD program.

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Finally, I thank Judith, Kristy and Corrine. Kristy and Corrine have been waiting for this announcement for half their lives. Girls, the thesis is finished! Thanks for your patience and your love. And Judith, thank you. I owe you everything, so it is to you that I dedicate this thesis.

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CHAPTER ONE

Chapter One is divided into seven sections. Section I states the research questions addressed by this research and Section II discusses the potential contributions of the research. The next two sections look at advantages of flexible automation and at evidence that Canada is lagging in the adoption of advanced technologies. Section V presents some key definitions, assumptions and boundaries of the study and Section VI lists the actual hypotheses tested by the study. The final section outlines the remaining chapters of the thesis.

Section I: Research Questions

Critics have charged that obsolescent managerial accounting and control systems are a barrier to the adoption of flexible automation in North American manufacturing firms. Flexible automation includes robotics and other computer controlled, reprogrammable machinery and equipment.

Traditional managerial accounting and control systems (MACS) are said to be retarding the adoption of flexible automation in two ways:

1. **The use of accounting measures to evaluate performance forces managers to strive for short-term results and ignore the long-term welfare of their firms. Because the adoption of flexible automation may depress short-term accounting results, managers who are evaluated by these results will avoid adopting new technologies.**

2. Many of the benefits of flexible automation are difficult to quantify in financial terms Capital budgeting systems that emphasize financial criteria for justifying investments are thus biased against flexible automation.

A number of changes in the characteristics and uses of MACS have been proposed to make these systems more supportive of flexible automation Four of the most common prescriptions are

1. Top management should place less emphasis on accounting measures of performance in their evaluation of lower level managers

2. Top management should ensure that accounting measures properly reflect the long-term objectives of the firm

3. Top management should place less emphasis on financial criteria in the justification of investments in flexible automation.

4. Top management should make it easier to justify investments in flexible automation by considering some of the less easily quantified benefits of new technologies.

The validity of these prescriptions has been unsubstantiated by empirical research. This dissertation thus attempts to answer four specific questions

1. Is the use of accounting measures to evaluate performance related to the adoption of flexible automation?

2. Are the time horizons implicit in MACS related to the adoption of flexible automation?

3. Is the use of financial criteria in evaluating capital budgeting proposals related to the adoption of flexible automation?

4. Are difficulties in quantifying flexible automation benefits related to the adoption of flexible automation?

The research was conducted in 32 General Motors of Canada part suppliers. Adoption was measured at the level of the manufacturing plant. Self-administered questionnaires and face-to-face interviews of plant managers were used to assess the MACS of each plant and each plant's adoption of flexible automation. Statistical tests were then conducted to see if the characteristics and uses of MACS were related to adoption

Section II Relevancy of Research

H. Contribution to Management Practice

The results of this research will be of interest to top managers who want to promote the adoption of flexible automation in their firms.[1] Two recent surveys demonstrate that Canadian managers are concerned that MACS are retarding investment in new technology. The Thompson Lightstone survey of 376 Ontario manufacturing managers found cost justification ranked second, right after problems in finding qualified people to operate new equipment, as a barrier to innovation (Ontario Centre for Advanced Manufacturing 1986). In the second survey, conducted by the Canadian Institute of Metalworking in conjunction with the National Association of Accountants (U.S.), Canadian managers were asked to list the obstacles that stand in the way of improving

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[1] As Hill & Dimnik (1986) point out, it is important that MACS be fine-tuned to support the amount and type of investment deemed necessary by top management.

investment decisions in advanced manufacturing technologies. Twenty-two percent of the respondents cited capital budget limitations, 19% cited orientation towards short-term results, and 15% cited the inaccuracy or unreliability of cost/benefit forecasts Another question in the same survey, asked respondents to list the obstacles to improving performance measurement systems. The most frequently mentioned obstacles were emphasis of management on short-term financial results, inappropriate performance measurement concepts, and conservative accounting and financial practices (Canadian CAD/CAM Council 1987)

In Chapter Two, I will present a wide-ranging literature that contends that managers consider MACS as a barrier to adoption It is not clear from reading the literature reviewed in Chapter Two, or from examining the two studies cited above, whether managerial concerns about MACS and adoption are grounded in fact. It is one thing to say that managers think MACS is a barrier to adoption and another thing to show that certain characteristics and uses of MACS are indeed related to the adoption of flexible automation. One cannot even be sure that managers really believe that MACS are a problem in adoption. MACS are so often criticized in the media that what passes as management opinion may simply reflect what managers are reading.

II.B. Contribution to Accounting and Accounting Research

Commenting on the role of MACS in fostering short-term time horizons, Merchant & Bruns (1986) write:

> In the first half of this decade, managers have been accused of selfish actions ~~and management~~ myopia. Managers allegedly overemphasize short decision horizons. In most cases, these allegations have been based on the presumed effects of performance measurement and evaluation systems, which create situations where managers take actions that make them look good in the short term but are not good for shareholders, long-term corporate health, or the national economy (p.56, Emphasis Added).

The Concise Oxford Dictionary defines "allegation" as an "assertion (especially one not proved)," and "presumed" as "assumed, taken for granted." Research on the topic of MACS and adoption of flexible automation is needed because criticisms of MACS and proposed changes to MACS are based on perceptions that MACS are retarding adoption and on assumptions that the suggested changes would promote adoption.

In discussing accounting research, Ijiri (1967) states:

> Unless we can show that the different figures (or, more precisely, different patterns of figures) lead to different decisions under a given set of conditions, there is no point arguing the merits or demerits of alternative accounting methods (p. 150).

There is an onus on accounting researchers to show that characteristics and uses of MACS make a difference in the adoption of advanced technologies and to prove the efficacy of any proposed changes to those systems.

Kaplan (1983) has argued that accounting researchers must face the challenge of devising "new internal accounting systems that will be supportive" of the adoption and implementation of advanced manufacturing technologies. One of his suggestions is to

> Identify U.S. firms that have been using non-financial performance measures for senior and/or plant managers, [and] compare the performance of these firms (as measured say, by stock price returns, market share, or product innovation) relative to those of a comparable set of firms using mostly financial measures of performance (p. 702).

The intent and methodology of this research are congruent with Kaplan's suggestion. The study compares the MACS of Canadian plants which have achieved various levels of adoption of flexible automation. Given the focus on plants and plant managers, it is logical that performance be defined in terms of <u>process</u> innovation and that MACS include both performance measurement <u>and</u> capital budgeting systems.

The goals of this thesis are also consistent with a number of other proposed and ongoing research projects. In Canada, the Canadian CAD/CAM Council (1987) has recommended that the federal government fund a two-year, $200,000 project, to "develop new methods of calculating the financial justification of Computer Integrated Manufacturing by recognizing modern competitive trends in manufacturing."

In the United States, the National Association of Accountants (NAA) has undertaken three studies of MACS and advanced technology.[2] Two of the projects are co-sponsored by CAM-I (Computer Aided Manufacturing-International). The joint NAA/CAM-I studies have been applauded by writers in various management publications (Ashburn 1986, Barrie 1986, Port 1987).

Elsewhere, INSEAD (European Institute of Business Administration), has initiated a study of "Performance Indicators in the Technology Function." Initial results of the INSEAD project confirm the need for more study of the role of MACS in the adoption and implementation of advanced technologies (Troberg 1986).

It is evident there is a need to study the relationship between MACS and adoption. I will now present some reasons why the adoption of flexible automation is an issue of concern. I will begin by discussing several aspects of manufacturing flexibility and then go on to describe how flexible automation may serve as a competitive weapon and a catalyst for organizational change. Finally, I will show that Canada lags its competitors in adopting flexible automation.

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[2] The three NAA funded projects are:

1. The State of the Art of Cost Management Systems Practice
2. The State of the Art of Cost Management Systems Practice (Literature Search)
3. Cost Accounting for Factory Automation

Section III: Importance of Flexible Automation

III.A. Flexibility of Process, Product and Capacity

Flexible automation technologies share a common feature: their operation is controlled by computer. Within certain limits, changes in product or manufacturing process can be accomplished by changing the computer software that controls the machinery. This software flexibility may be compared with the flexibility of production technologies traditionally used in job shop and mass production situations.

Through the intensive use of labour, job shops can produce a variety of parts in small volumes. Within limits, changes in process can be accomplished by changes in human software (ie. retraining). However even minor process or product changes may require expensive and time consuming hardware changes in a traditional, automated mass production system (Ayres & Miller 1983).

Besides having process and product flexibility, computer controlled equipment is flexible in another sense. Flexible automation equipment may be purchased in less "lumpy" amounts than hard automation equipment. In other words, flexible automation capacity can be adjusted in smaller increments than can hard automation capacity. And, because a variety of parts can be produced with the same equipment, flexible automation may be better utilized than hard automation. Incremental capacity adjustments and maximum utilization of machinery are particularly relevant in the context of the small Canadian market (McGourty 1985).

The flexibility of computer operated machinery does not come without costs. Figure 1.1 shows how flexible automation, applied to batch volumes, trades off the advantages and disadvantages of job shop and mass production.

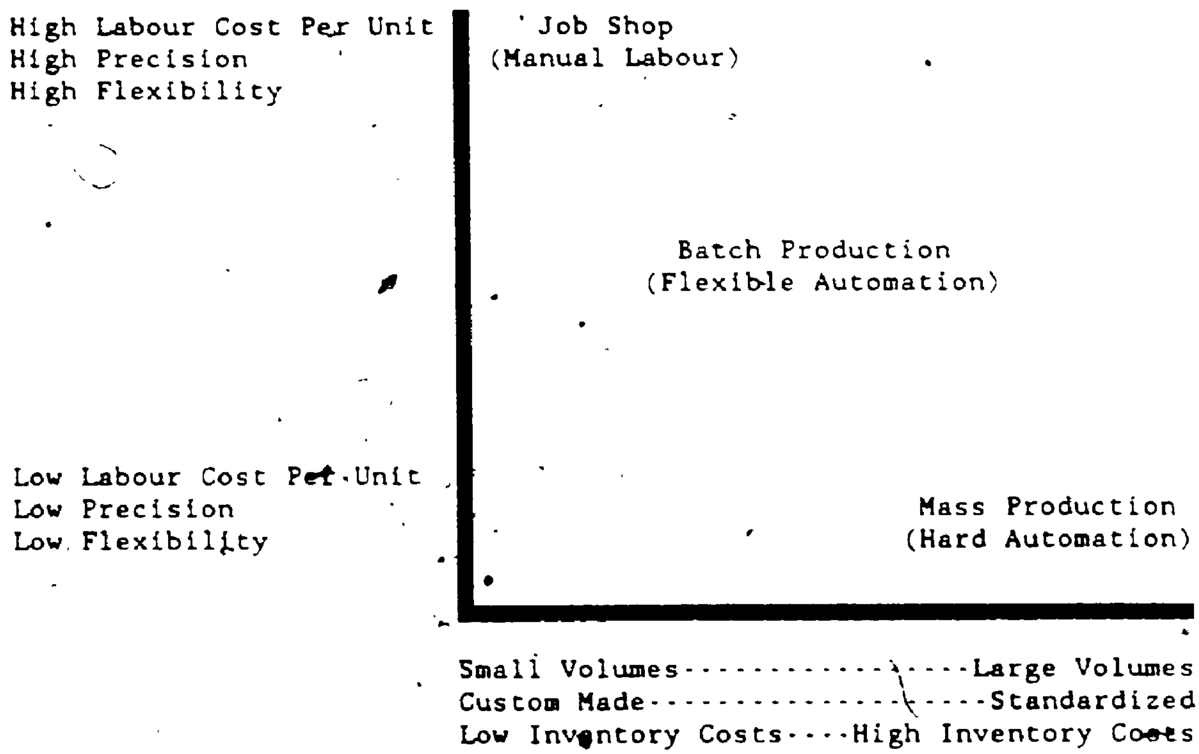
Figure 1.1 may be summarized by saying that the use of computer-controlled machines for batch production realizes advantages of scale over job shop production and advantages of scope over mass production (Jelinek & Goldhar 1983, Jelinek & Goldhar 1984).

III.B. Flexible Automation as Competitive Weapon

Since the early 1980's, North American managers have been exhorted to adopt flexible automation in order to survive global competition. The Canadian Manufacturers' Association (1982) states:

> A firm's most important competitor in the 1980's may not be the company on the other side of town, but a firm located across the border or perhaps across the ocean. To be competitive now means to be internationally competitive (p. 7).

Figure 1.1
Flexible Automation Trade-Offs



Adapted from:
Jelinek & Goldhar (1983)
Ayres & Miller (1983)
Jaikumar (1984)

North American manufacturers are being challenged by foreign firms with low cost labour, by foreign firms with a capability to respond quickly to innovation and by foreign firms which produce high value goods. Flexible automation is seen as the key to meeting these three competitive threats.

V.A. Management Accounting and Control Systems (MACS).

In this study, the term "Management Accounting and Control Systems" (MACS), refers to performance measurement and reward systems and capital budgeting systems. A performance measurement and reward system may include budgets and accounting measures of performance.

Capital budgeting systems play a direct role in the adoption of flexible automation. A capital budgeting system provides a means of sifting through alternative proposals to select those that best meet top management objectives and it provides clues to project initiators and supporters about the strategic direction in which top management may wish to take the firm (Hill & Dimnik 1986).

Performance measurement and reward systems play a less obvious role in adoption:

> An often overlooked internal characteristic which can be manipulated to improve the capital budgeting process is the firm's reward structure. The path and concurrent rewards along the path that a proposal follows from its originator in operations to its approval by top corporate executives can have a great deal of influence on (1) the projects selected (2) the quality of the cash flow and project lives estimates and (3) on the post audit information collected and utilized (Haka 1987, p. 36).

Commenting on Bower's (1970) work, Caves (1980) writes:

> Bower holds that a company's top management approves or rejects projects but has little direct influence on how they get defined or on which ones are pushed through the firm's lower levels of decision-making to become claimants for top-executive approval...Top management cannot keep the character and composition of the projects that rise for their approval from being colored by structural context. However, top management

low labour cost foreign manufacturers. Instead, North American manufacturers should take advantage of a well-trained and educated workforce and concentrate on the production of high-value goods. High-value goods are products of high quality, made-to-order products and products that embody the newest technologies. Using flexible automation is the most efficient way of producing high-value products (Reich 1983, Ayres & Miller 1983).

III.C.Flexible Automation as Change Agent

The adoption of even a single computer-controlled machine may precipitate change in what the firm does and how it does it. The adoption of flexible automation may be a catalyst for closer cooperation between managers of various departments, for a rationalization of organizational structure and procedures (eg. just-in-time), and for greater awareness of product quality (Ayres & Miller 1983, Arbose 1985, Regan 1985, Skinner 1986). In short, flexible automation may make North American firms more like their European and Japanese counterparts who are said to be better organized for global competition. Thus, flexible automation may not only help North American firms compensate for organizational shortcomings (Boltz 1985), but the new technology may change the organizations themselves.

III.D. Summary of Flexible Automation Benefits

Champions of advanced technologies maintain that North American manufacturers must adopt new manufacturing technologies in order to survive global competition. As Honeywell Inc CEO, Rod Bilodeau once warned:

> Make no mistake about it, we're in an economic war and if we, as a country, don't get off our butts and improve our competitiveness, we're going to lose this war and pay a heavier price than we could ever imagine. (Canadian Manufacturers' Association 1982, p. 1).

To put it even more succinctly, North American manufacturers must automate, emigrate or evaporate.

Section IV: Adoption of Flexible Automation in Canada

Given the apparent advantages of flexible automation, one might expect there to be widespread adoption of these technologies. However, this is not the case:

> Canada's persistent lag in the introduction and use of computer-based technologies is an urgent national problem of major proportions. The diffusion of process technologies is too slow. The capital investment needed for the introduction of advanced equipment is also lagging seriously. Without that spending, process automation just cannot take place (Economic Council of Canada 1987, p. 6).

In the next few pages I will present evidence that Canadian firms lag behind firms in other countries in the adoption of flexible automation technologies.[3] I will begin with some statistics on the adoption of computer numerical control machines (CNC machines).

As of 1983, Canada had 3500 numerical control machines compared to Japan's more than 300,000. Adjusting for the fact that Canada's manufacturing sector is one-seventh the size of Japan's, Japan still has a fifteen to one advantage in numerically controlled tools (Ontario Ministry of Industry, Trade and Technology 1985). Furthermore, as shown in Table 1.1, the gap between Canada and Japan may be increasing only 4.4% of the new machine tools purchased in Canada in 1983 were numerically controlled compared to 38 1% of Japanese installations.[4]

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[3] A technology by technology comparison between Canadian and international adoption rates is presented in Litvak & Warner (1987).

[4] Though numerical control (NC) machines need not be operated by computer, they are considered reprogrammable. In any case, many of the references cited in this thesis do not make a distinction between NC and CNC (computer numerical control) machines.

Table 1.1
Numerical Control Machines as Percent of Machine Tool Consumption

Japan	38.1%
United States	12.9%
United Kingdom	8.1%
Canada	4.4%

Note: Percentages calculated on a unit basis

(Ontario Ministry of Industry, Trade and Technology 1985, p. 9)

A similar pattern emerges when Canadian usage of robots is compared to other nations. Table 1.2 shows that as of January 1, 1984, there were only 3.7 robots for every 10,000 workers in Canada compared to 32.1 in Japan, 20.2 in Sweden and 7.2 in West Germany.

Finally, looking at automated inspection and automated materials handling technologies, about 60% of Japanese manufacturing firms employing 100 or more workers were using these microelectronic technologies by 1982. Similar levels of adoption were not reached in Canada until 1985 (Economic Council of Canada 1987).

Table 1.2
International Comparison of Robot Usage
(as of January 1, 1984)

Country	Robots in Use	Manufacturing Employed	Robots per 10,000 Manufacturing Employed
Japan	45,000	14,010,000	32.1
Sweden	1,900	941,000	20.2
West Germany	4,800	6,652,000	7.2
Czechoslovakia	1,845	2,554,000	7.2
France	3,592	5,172,000	6.9
Belgium	514	872,000	5.9
U.S.	9,400	19,946,000	4.7
Italy	2,000	5,117,000	3.9
Canada	702	1,886,000	3.7
United Kingdom	1,753	5,641,000	3.1

(Ontario Ministry of Industry, Trade and Technology 1985, p IR-8)

Section V: Definitions, Assumptions and Boundaries

Having established that Canadian firms lag in the adoption of flexible automation and that this lag is undesirable, I will now return to a discussion of the research. This section establishes a framework for the study of the MACS-adoption relationship by presenting formal definitions of three key terms: MACS, plant managers and flexible automation. In defining these terms I will circumscribe the boundaries of the research and will explicitly state some major assumptions. After this is done, I will present the research hypotheses.

V.A. Management Accounting and Control Systems (MACS).

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Performance measurement and reward systems play a less obvious role in adoption:

> An often overlooked internal characteristic which can be manipulated to improve the capital budgeting process is the firm's reward structure. The path and concurrent rewards along the path that a proposal follows from its originator in operations to its approval by top corporate executives can have a great deal of influence on (1) the projects selected (2) the quality of the cash flow and project lives estimates and (3) on the post audit information collected and utilized (Haka 1987, p. 36).

Commenting on Bower's (1970) work, Caves (1980) writes:

> Bower holds that a company's top management approves or rejects projects but has little direct influence on how they get defined or on which ones are pushed through the firm's lower levels of decision-making to become claimants for top-executive approval...Top management cannot keep the character and composition of the projects that rise for their approval from being colored by structural context. However, top management

> <u>can</u> influence that structural context by means of the organization chart...and the measurement and reward system it employs (p. 76)

Implicit in Haka's and Bower's views of the adoption process is the idea of control. Capital budgeting and performance measurement and reward systems may be thought of as management controls systems (Itami 1977). Looking at adoption from a management control perspective requires the identification of controllers and controlled (Hofstede 1968, Tannenbaum 1968) There are two obvious choices of controller/controlled dyad: firm owners/top management or top management/lower level management A study of the owner/top management dyad would have to assume an open system perspective and examine some very broad social issues

> It's conventional wisdom now to say Canadian and American companies try so hard to look good today that they devote too little time and brainpower to how they'll do tomorrow There may be some question, however, about the root of the problem Maybe its less the fault of Big Business than of North Americans in general Do we all--workers, consumers, investors, and governments--press too hard to get it now (McArthur 1986, p F1)?

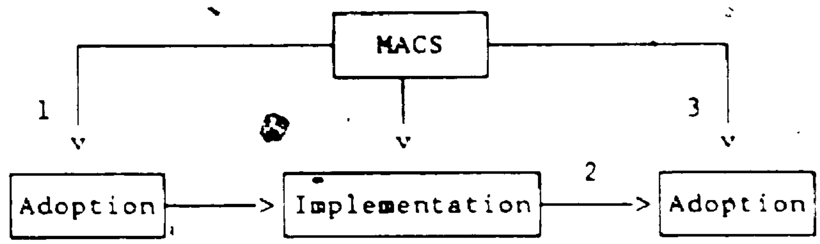
This thesis will not examine relationships between firm owners and top management nor address the broad social issues that such a perspective entails. The study is restricted to the internal systems of firms, and focuses on top management/lower level management control dyads

The domain of the research is narrowed in a second way. The study is restricted to the role of accounting in <u>adoption</u> Adoption or purchase of new technology may be viewed as the first phase of the innovation process. Implementation or utilization of new technology follows adoption (Zaltman et al. 1978, Marshall 1985).

Success or failure of implementing a new technology may affect the likelihood of subsequent equipment purchases (Gerwin 1981). For example, Northern Telecom did not purchase its first robot until 1981 but had such positive results from the technology that it had installed 128 robots by 1985 (Meffe 1985). Thus, MACS may have both a direct impact on adoption and an indirect impact through implementation. In terms of Figure 1.2, this research considers only the direct relationships (Arrows 1 and 3), and not the indirect relationships (Arrow 2). By studying how MACS relates to adoption, this research complements the recent accounting literature which has focused on the role of MACS in the implementation phase of innovation.[5]

[5] Examples of articles that deal with accounting and the implementation of advanced technologies are: Armitage & Skelton (1987), Chalos & Badger (1986), Dilts & Russell (1985), Littrell (1984), Seed (1984).

Figure 1.2
Direct and Indirect Effects of MACS on Adoption



V B Plant Managers

Plant managers are defined in terms of two criteria

1. A plant manager is a person who makes capital budget proposals to top management but does not have authority to approve them.

2 A plant manager is a person who is responsible for the operation of a manufacturing plant [6]

In choosing to study plant managers, I make two assumptions that plant managers play an important role in the adoption of flexible automation and that the use of MACS for performance measurement and decision-making is appropriate to the production function

[6] The people identified as plant managers held various titles in the sample firms: general manager, director of operations, operations manager, manufacturing manager, director of manufacturing, vice-president operations, president, and of course, plant manager

Bessant (1982) defines the adoption of a computer-controlled machine as a "manufacturing innovation":

> By this is meant the type of innovation which changes neither the product nor the basic process, but only some elements in the process. For example, despite its radical nature, the use of an industrial robot does not change the way in which cars are made; they are still welded together (p. 119).

Manufacturing innovations are a subset of process innovations. They are equipment and control system changes of an incremental nature and are relatively inexpensive. Though a manufacturing innovation may have a strategic implication, purchasing the equipment is usually a tactical decision and is directly influenced by a plant manager (Bessant 1982).

Bessant's views on the role of plant managers are supported by the innovation literature which suggests that it is the technical core, the people closest to the technology, that come up with proposals to change that technology (Daft 1978, Kimberly & Evanisko 1981, Zmud 1982). In the context of this study, plant managers would be expected to propose projects within guidelines set by top management and present those project proposals to top management for their approval.[7]

Not all agree that investment in flexible automation is or should be a tactical decision. Some argue that because of its complexity and strategic implications, the adoption of flexible automation should be under the purview of top management (Gold 1982, Tanner 1984). However, even if investment in advanced technologies is not the direct

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[7] This is what Brealey et al. (1986) refer to as "bottom up" capital budgeting and is consistent with the capital budgeting models described by Bower (1970) and King (1975).

responsibility of lower level management, these managers can set up roadblocks to adoption by actively fighting against proposed purchases of flexible automation, or simply by not initiating investment proposals (Haka 1987, Mitchell & Mabert 1986).

A second assumption implied in the decision to study manufacturing managers is that MACS are an appropriate tool for managing the manufacturing function MACS have an important but limited use in many situations, but MACS are extensively, and appropriately, used in the management of the manufacturing function (Hayes 1977, Otley 1978, Merchant 1981). MACS are thought to be technically correct for performance measurement and decision-making in situations where beliefs about cause and effect relationships are complete and standards of desirability crystallized. Such a situation is thought to exist in the buffered environment of the production core (Hayes 1977)

V.C Flexible Automation

In this study, the term flexible automation is the name of a set which includes the following manufacturing technologies:

> Robots: reprogrammable, multifunctional manipulators designed to move workpieces or tools along various paths
>
> Computer numerical control machines (CNC): devices which tool metal according to programmed instructions
>
> Programmable Controllers (PC): small, dedicated computers used to control or monitor a variety of production processes, other than metal machining

Automated materials handling equipment: systems used to automatically move and store parts and raw materials throughout the manufacturing process

Computer-aided inspection and testing devices: programmable devices (including robots and PCs) used to automatically measure or test production output

CAD/CAM: integration between computer-assisted design technologies (CAD) and computer-assisted manufacturing (CAM)

This definition of flexible automation is consistent with the use of the term in the literature and in several recent surveys of Canadian manufacturers (Ontario Ministry of Industry, Trade and Technology 1985, Automotive Industry Human Resources Task Force 1985, Ontario Centre for Advanced Manufacturing 1986).

Adoption of flexible automation can be measured at either plant or multi-plant (firm) levels. Figure 1.3 shows the various combinations of unit of analysis and control dyad that were considered for this research. Choosing to study plant managers narrowed the alternatives to Cell 1 or 2 but did not resolve the issue of whether to define adoption at plant or firm level.

Figure 1.3
Choosing Informants and Defining Adoption

	Plant	Multi-Plant
Top Management/Plant Managers Control Dyads	Cell 1	Cell 2
Owners/Top Management Control Dyads	Cell 3	Cell 4

Unit of Analysis for Measuring Adoption

A procedure consistent with Cell 2 would be to survey several plant managers in each firm. Managers would provide multiple observations on the characteristics and uses of MACS for each firm. These observations would be averaged in some way and each firm's MACS scores would be related to an adoption variable which would itself be calculated by averaging the flexible automation technologies in the firm's plants.

The problem with this approach is that levels of adoption of flexible automation could vary widely among plants within the same firm. And, as shown by Hopwood (1972), [illegible]ley (1978) and Hill (1984), the characteristics and uses of MACS can also differ from plant to plant in the same firm. Thus analyzing MACS and adoption at the firm (or multi-plant) level would confound any relationship between MACS and adoption

I therefore concluded that a Cell 1 approach would be the appropriate choice for this research and that adoption would be defined in terms of flexible automation technologies at the plant level.[8]

Section VI: Hypotheses

VI.A. Model A: Main Hypotheses

The research questions will be addressed by testing four null hypotheses:

H1 Emphasis on accounting measures in evaluating managers is not related to the level of adoption of flexible automation.

H2 The time horizon of accounting measures is not related to the level of adoption of flexible automation.

H3 Emphasis on financial criteria in justifying investment in flexible automation is not related to the level of adoption of such technologies.

H4 Difficulty in quantifying the benefits of flexible automation is not related to the level of adoption of such technologies.

Table 1.3 describes the five main constructs in the study and presents interpretations of high and low scores on the variables that will be used to measure them. Figure 1.4 is a pictorial representation of the four hypotheses.

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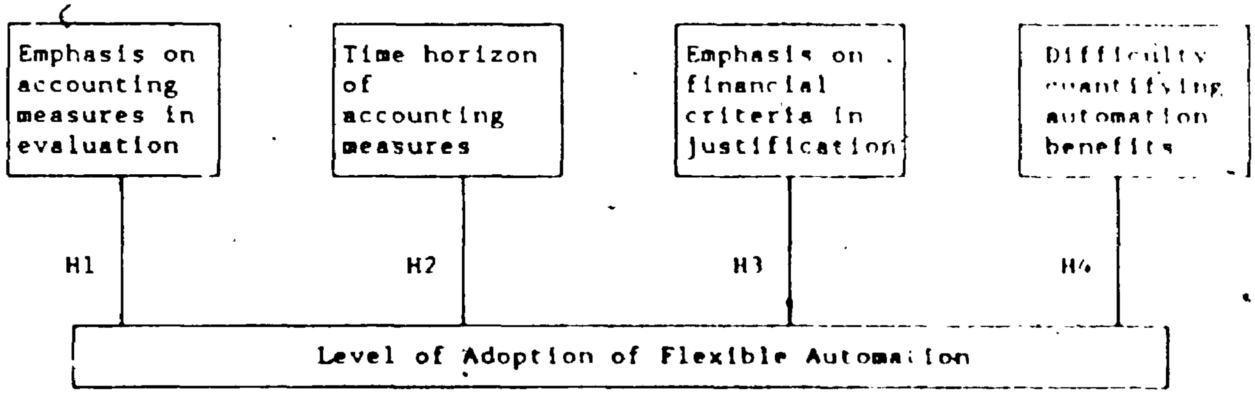
[8] In his study of the automotive industry, Abernathy (1978) argues for the use of a special unit of analysis that encompasses "both the product and the characteristics of the manufacturing unit that produced it." His unit of analysis is the "productive unit" which is defined as "an integral production process that is located in one place under a common management to produce a particular product line." Abernathy notes that an automotive parts plant is an example of a productive unit.

Table 1.3
Model A Constructs

Construct Definition	Meaning of High Score on Variable	Meaning of Low Score on Variable
emphasis on accounting measures in performance evaluations	accounting used to evaluate	accounting not used to evaluate
time horizon of accounting measures	accounting focus long-term	accounting focus short-term
emphasis on financial criteria in justifying capital investments	accounting used to justify	accounting not used to justify
difficulty in quantifying benefits of flexible automation	benefits hard to quantify	benefits easy to quantify
level of adoption of flexible automation	many computer-run machines	no computer-run machines

Figure 1.4
Model A



VI.B.Model B: Additional Hypotheses

Several studies have looked at the relationship between MACS and decentralization and between adoption and decentralization. Generally speaking, it is thought that a decentralized organizational structure is positively related to innovation (Rogers 1983), especially when the innovation relates to the technical core or production process (Daft 1978). However, Zmud (1982) suggests that while decentralization may foster the initiation of proposals for new products or processes, adoption itself is more compatible with centralization. This may be especially true when lower level managers are opposed to an innovation:

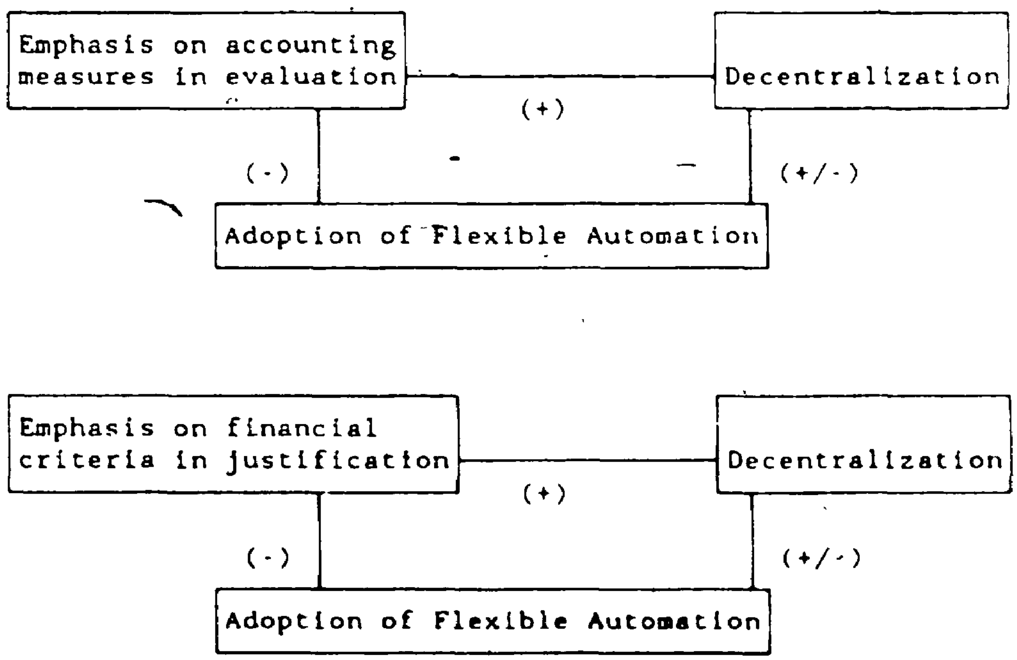
> Innovation may be compatible or incompatible with the interest of organizational members where incompatibility might be linked to irrelevancy, to fear of change, to the inconvenience of change, to power shifts, etc. Given that a realm of innovation was incompatible with an organization's lower-level members, it is unlikely than any "expansion" in individual initiative brought about by decentralization would result in increased innovation. More innovation, in fact, might be observed if it had been ordained by a centralized hierarchy (Zmud 1982, p. 1423).

Thus, depending on whether top or lower level managers support or oppose adoption of flexible automation, decentralization may be positively or negatively related to adoption.

The relationship between MACS and decentralization is more straightforward. Generally speaking, it is thought that decentralization is positively related to the use of MACS (Bruns & Waterhouse 1975, Merchant 1981). In decentralized organizations, top management rely on MACS for measuring performance and making investment decisions.

Herein lies the seed of an interesting problem. If the relationship among the MACS variables, decentralization and adoption is as portrayed in Figure 1.5, then decentralization might confound the <u>observed</u> relationships between the MACS variables and adoption. A failure to reject H1 or H3 may mean that an emphasis on MACS for evaluation or capital budgeting is not a factor in adoption or that other factors such as decentralization are "interfering" with the impact of MACS on adoption.[9]

Figure 1.5
Assumed Relationships Among MACS, Decentralization and Adoption



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[9] The same argument holds if H1 and H3 are rejected. The observed relationships between the MACS and adoption variables may be due other variables.

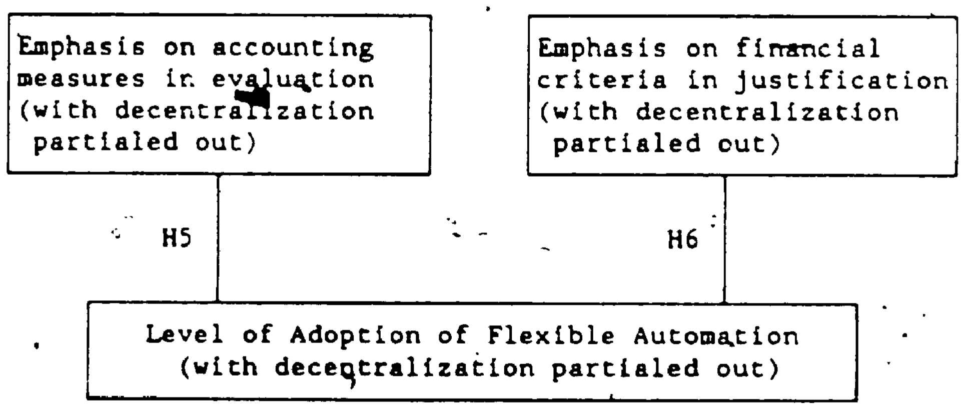
Model B examines the relationships among the H1 and H3 variables, adoption and decentralization. The two additional hypotheses examined in this study are:

H5 There is no relationship between emphasis on accounting measures in evaluating managers and level of adoption of flexible automation after the effects of decentralization are partialed out.

H6 There is no relationship between emphasis on financial criteria in justifying investment in advanced technologies and level of adoption of flexible automation, after the effects of decentralization are partialed out.

Figure 1.6 diagrams the Model B hypotheses.

Figure 1.6
Model B



VI.C. Assessing Threats to the Validity of the Results

For completeness, and to resolve threats to the validity of this study, a number of other variables were measured and other relationships tested. These "other" variables are introduced in Chapter Four and are described in the context of the discussions of Chapters Five and Six.

Section VII: Outline of Remaining Chapters

Chapter One has shown that this study is managerially and academically relevant and has presented a framework for the analysis of six hypotheses of the relationship between MACS and adoption of flexible automation. Chapter Two reviews a literature that contends that MACS block the adoption of flexible automation. Though this literature offers a number of ways of surmounting the MACS barrier, it never demonstrates that MACS are a barrier to adoption, nor does it provide evidence that suggested improvements will result in higher levels of adoption. Chapter Three begins with a description of the research methodology and of the sample chosen for the study. This is followed by notes on the four groups of General Motors of Canada part suppliers that participated in the study. Chapter Four shows how the variables in Model A and B were operationalized and Chapter Five summarizes the research results and presents statistical tests of the six hypotheses of Models A and B. Chapter Six draws some conclusions from the study results and makes some recommendations for future research.

CHAPTER TWO

This chapter is divided into three sections. Section I reviews the works of authors who are critical of the role of MACS in the adoption of advanced technologies and who prescribe changes to current systems. The objectives of this section are three-fold: to demonstrate there is a substantial body of literature that assumes that certain characteristics and uses of MACS affect adoption of flexible automation, to identify those characteristics and uses of MACS that are thought to impact on adoption, and to show the need for empirical evidence to support the presumptions of this literature.

Section II describes the few empirical studies that have examined the role of MACS in the adoption of flexible automation and Section III summarizes the chapter.

Section I: The Normative Literature

If this section is to meet its objectives, the works reviewed here must be seen as being a fair representation of current views on management accounting and adoption of flexible automation. An explanation of the manner in which the works were identified is thus in order. The literature review began with a manual search of recent periodicals and was followed, in September, 1986, by a computer search of the ABI/Inform Data Base which references more than 660 business and management publications from the United States, Canada, Europe, Australia and Japan. A computer search of two engineering data bases was also conducted. Though less productive, this search did identify several engineering and production management journals that were subsequently investigated. The process of manual and computer searches resulted in a list of 34 books, articles and editorials which are representative of the literature on MACS and adoption of advanced technologies.

The materials identified in the searches were found to be almost entirely of a normative nature. These materials were coded for content and the results of the coding process are presented in Appendix A and summarized in Table 2.1.

Table 2.1 demonstrates that two concerns pervade the literature: that accounting-based performance evaluations are overly concerned with the short-term and that accounting-based justification processes have difficulty in supporting investments in advanced technologies. Similarly, the coding process confirmed that most proposed changes to MACS may be classified into one of the following four categories:

1. Top management should place less emphasis on accounting measures of performance in their evaluation of lower level managers.

2. Top management should ensure that accounting measures properly reflect the long-term objectives of the firm.

3. Top management should place less emphasis on financial criteria in the justification of investments in flexible automation.

4. Top management should make it easier to justify investments in flexible automation by considering

some of the less easily quantified benefits of new technologies.

Table 2.1
Coding of the Normative Literature

Coding Category	Number of Items*
<u>Problems with MACS</u>.	
Evaluation Period Too Short	12
Can't Justify Flexible Automation	26
Other	5
<u>Proposed Solutions to Problems</u>:	
Less Emphasis on Accounting Measures in Evaluation	5
Longer Time Horizon for MACS Objectives	16
Less Emphasis On Financial Criteria In Justification	14
Less Difficulty in Quantify Automation Benefits	19
Other	10
<u>Research Methodology Employed</u>:	
Model Building / Speculative	16
Personal Experiences / Anecdotes	10
Case Study / Survey	8
<u>Source Journal</u>:	
Management Literature	13
Production/Engineering Literature	13
Accounting Literature	8

* In some cases items fall into more than one coding category and thus category totals may not equal 34.

(Table 2.1 is a summary of Appendix A.)

Table 2.1 shows that only 8 of the 34 normative works employed an empirical methodology.[1] However, none of these empirical works studied

[1] Methodologies were classified according to a scheme adapted from Kaplan (1986c) and Kelmstine & Maher (1984).

accounting and adoption of flexible automation per se. That is, while 8 of the works were based on empirical studies, those studies did not specifically examine the relationship between MACS and adoption of flexible technology. The authors of these works only speculated on the role of MACS in the adoption of flexible automation

The final category in Table 2.1 is "Source Publications." Each of the 34 items of the normative literature were classified into one of three categories depending on whether the item's intended audience was general management, production/engineering personnel, or accountants. The remainder of Section I is an overview of the normative literature organized around these three "target audiences."

I.A.The Management Literature

Picture this: a man in a three piece suit struggles in a tug of war with a robot. The man leans backward trying to pull a bundle of money out of the robot's grip. The man's upturned face is covered with a book. Looking closely you can see that the book is an accounting ledger. And then you get the picture: here's a manager blinded by accounting, refusing to invest in flexible automation

The above is a description of a drawing that introduces an article in Management Today (Sheridan 1986). Sheridan criticizes managers for maximizing short-term accounting objectives and for emphasizing return-on-investment and cost savings in justification of advanced technologies. He suggests that top managers should use non-financial criteria in performance evaluations, that they should adopt longer time horizons, and that they should link evaluations of investments in new technologies with strategic thinking. He proposes that investments in flexible automation not be justified strictly on cost avoidance but also on improved customer service, shorter lead times and increased quality. Sheridan concludes:

> The message is one both for accountants and for general managements. Accountants must rethink their costing and evaluating systems. Yesterday's systems cannot be allowed to be a brake on today's -- let alone tomorrow's -- technological advances ... But accounting is too important to be left to the accountants. General management too, must be aware of the drawbacks and deficiencies of their current measuring systems and press for improvements. It is up to top management to ensure that the finance function plays its part (p. 75).

Sheridan's concern that MACS pressure managers to aim for quick payoffs has been a theme in the management literature for decades (Banks & Wheelwright 1979, Rappaport 1978). However, the insidious effects of short-term accounting goals on flexible automation were first suggested by Hayes & Abernathy (1980). In their article, "Managing Our Way to Economic Decline," Hayes & Abernathy raise a number of alternative hypotheses for what they describe as the decline of North American manufacturing, but ultimately they lay a big part of the blame on MACS:

> Having never lost sight of the need to be technologically competitive over the long run, European and Japanese managers are extremely careful to make the necessary arrangements and investments today. And their daily concern with the rather basic issue of long-term survival adds perspective to such matters as short-term ROI or rate of growth. The time line by which they manage is long, and it has made them painstakingly attentive to the means for keeping their companies technologically competitive. Of course, they pay attention to the numbers ... But they are also aware that tomorrow will be no better unless they constantly try to develop new processes, enter new markets, and offer superior -- even unique -- products (p. 77).

It has been said that no other article in the Harvard Business Review's sixty years of publishing "excited quite the same degree of reaction" as "Managing Our Way to Economic Decline" (Kantrow 1983). Indeed Hayes & Abernathy's views permeate the normative literature.

In a follow up to Hayes & Abernathy, Hayes & Garvin (1982) shift from criticism of short term performance measurements to criticism of the use of the discounted cash flow (DCF) method in evaluating investments in advanced technologies. Hayes & Garvin argue that although the DCF method may be suitable for evaluating tactical proposals (eg replacing a single machine), it is inappropriate for examining investments in advanced technologies. Investments in flexible automation must be evaluated from a strategic perspective. Managers must consider the interdependencies between investments in flexible automation and how these investments affect their firm's ability to compete.

The attack on DCF, one of the cornerstones of "scientific" management, has increased in the past few years. However, few alternatives have been offered. The Hayes & Garvin "alternative" is lowering hurdle rates: lower rates increase managers' time horizons and make flexible automation more attractive. Pearson (1986) concurs with this advice. He suggests hurdle rates be lowered a few percentage points -- a "strategic discount" -- for investments in advanced technology.

A more radical alternative to DCF is the application of an options pricing approach (Myers 1984, Kester 1984, Rizzi 1984, Hill & Dimnik

1986). Though intuitively attractive, options pricing theory would be difficult to apply in a formal analysis of real-world investments.

Kaplan (1986a) contends that there are no "logic" problems with DCF but that there are problems in correctly applying DCF techniques. He recommends managers calculate the net present value of proposed investments in advanced technology using lowered discount rates and including all quantifiable costs and benefits. The (usually) negative value of a proposed investment should then be weighed against the unquantified benefits. If management can convince themselves that the "other benefits" will exceed the cost, then the purchase should be made. In practice, Kaplan's approach ends up being very similar to the options pricing approach (Hill & Dimnik 1986).

In general, the proposed modifications and alternatives to DCF ask managers to link investment proposals to overall market strategies and to evaluate proposals on their contribution to the broad goals and objectives of the organization. Such suggestions may fly in the face of North American managements' "preoccupation with analytic detachment" (Hayes & Abernathy 1980) but they are consistent with the Japanese way of doing things:

> Japanese firms generally appear to be much less "numbers driven" than companies in the United States. That is fortuitous, since many Japanese firms are using imprecise analytical techniques ... The implication is that the discussion and analysis of underlying assumptions may be more important than the numerical processing technique employed ... It may be that Japanese firms have done a better job of focusing attention on critical input assumptions including possible scenarios and management-responses (Hodder 1986, p. 22).

To summarize, writers in the management literature see two problems with MACS: . the use of short-term accounting measures in evaluating management performance and the use of analytic techniques like DCF for strategic investments. Commonly proposed solutions are to lengthen managers' time horizons by lengthening the time period for evaluation and by lowering hurdle rates, and to employ non-financial, strategic evaluations of proposed investments.

I.B. Production/Engineering Literature

The management literature reviewed above attempts to reconcile aggressive technological strategies with fiscal responsibility (Hill & Dimnik 1986). Implicit in the management literature is the understanding that not all technology is good technology. This is not the case in the production/engineering literature where the absolute benefits of flexible automation are taken for granted and the focus is on finding ways to convince top management of the logic of investing in computer controlled equipment.

Canada (1986) starts off his annotated bibliography on justification of computer-integrated manufacturing (CIM) systems with the comment.

> Over the past several years there have been increasingly forceful statements by industry leaders and authors regarding the inadequacies of traditional discounted cash flow as well as accounting-based methodologies for evaluating and justifying CIM systems. The roots of the perceived weaknesses are that those traditional methodologies (1) fail to adequately quantify and incorporate the broad almost-pervasive benefits of CIM systems, and

> (2) often blind firms to the effects of status quo complacency (p. 137).

Canada's bibliography includes 52 entries that are "subjective overviews/guidelines on justification" and 35 items that demonstrate "quantitative techniques/analysis methodologies for justification." The "subjective" vs "quantitative" dichotomy will be followed in this summary of the production/engineering literature.

I.B.1. Subjective Overviews/Guidelines

Many of the "subjective" articles in the production/engineering literature are reports of executive roundtables. For example, Huber (1985) states that "traditional financial justification procedures ... are quite likely the single greatest barrier to the utilization of new manufacturing technologies by U.S. manufacturing industries," and then goes on to ask a number of executives for their advice on surmounting the MACS barrier. One suggestion is to include the many unmeasurable benefits of advanced technologies in the justification process. Another suggestion is to ensure the investment process is driven by a long-range competitive strategy. Huber concludes with a few brief case studies of successful adoptions. The cases show that top management has had to de-emphasize traditional financial methods of evaluation in order to promote the adoption of flexible automation. For example, Allen-Bradley President J.T. O'Rourke says that his company's investment in a computer-controlled production line would not have been made had the project been evaluated on the basis of the "old ROA methods."

Similar sentiments are expressed in an article by General Electric executive, F. Curtis, who tells managers they must grasp two basic concepts: traditional "hard-number" methods of economic justification just don't work any more and one should not be afraid of "soft numbers" (Editors of Material Handling and Engineering 1985)

I.B.2.Quantitative Techniques/Analysis Methodologies

The threatened abandonment of traditional quantitative techniques has caused some consternation in the ranks of experts on the topic

> To ensure a progressive future, engineering economic analysis procedures and approaches must evolve to evaluate the economic aspects of changing technology, or alternative techniques will be found to justify new purchases and innovative designs. We already realize some of these new techniques in the justification of new technology -- robotics, flexible manufacturing systems, software systems, etc. -- by the use of vague reasons such as "technology," "labour replacement," "competition," etc., when classical economic analysis shows the suggested design to be a poor or risky choice (Blank 1985, p 227).

Blank (1985) discusses three ways in which engineering economics is adapting to the need for new methods of justification incorporating elements of strategic-planning in investment analyses, improving estimation and tracking of cost components, and designing and using software systems in analyzing investment proposals

Utecht (1986) and Powell (1986) identify some of the benefits not normally considered in the evaluation of flexible automation proposals Bernard (1986), while agreeing with the need for strategy-oriented methods of justification, argues that such an approach is not possible using the accounting profession's "highly structured methods" of allocating resources:

> ... Convincing top management of the need to invest in new technology and then justifying it is often more of an art than a science. Rather than relying on some type of "creative" accounting procedure to reduce all of the intangibles to dollars and cents in order to calculate a precise economic answer using imprecise or highly subjective source data, one approach is to use some type of structured project methodology to analyze the relative advantages and disadvantages to the firm (p. 52).

Bernard goes on to present a non-financial, multi-criteria evaluation technique for investments in new technology. Taking a similar tack, Frazelle (1985) and Sullivan (1986) recommend evaluation techniques that require managers to identify financial and non-financial criteria (eg. ROI, flexibility, safety, compatibility, maintainability), to subjectively weigh the criteria, and to rank alternative proposals according to the weighted criteria.

To sum up the production/engineering literature, there is a consensus that changes must be made to current accounting practices. One group, mostly production managers, suggests that investments in flexible management cannot be analyzed by conventional methods. They advocate making investments on faith. Academics and professional engineers are responding to the criticisms of traditional justification methods by suggesting improvements to those methods and by developing alternatives to them. There is general agreement that financial issues should be downplayed in favour of strategic issues and that more of the "soft" benefits of flexible automation should be considered in the justification process.

I.C. Accounting Literature

Kaplan (1983) issues a challenge to management accountants to "devise new internal accounting systems that will be supportive of the firm's new manufacturing strategy." In particular, he suggests the need for non-financial and longer-term measures of managerial performance and for new measures of the less-easily quantified benefits of advanced technologies that should be included in the justification process.

Kaplan (1984b) argues that inadequacies in existing performance measurement systems are hindering transitions to the organization and technology required for the "new industrial competition." He notes that "a narrow-minded focus on short-term financial indicators" can distort a firm's fixed asset acquisition program and that firms must "de-emphasize the use of accounting profits to measure near-term performance." Kaplan suggests that general managers augment accounting measures of performance with direct observation. "Management by Walking About will have to replace Managing by the Numbers."[2]

Kaplan (1985) testifies that the basic production model at the core of management accounting research and analysis is "an overly simplified, perhaps obsolete representation of the production situation confronted by corporations in the 1980's." He points out that "so called optimal

[2] Bruns & Waterhouse (1975) equate decentralization with "management by numbers" and centralization with "management by walking about." Thus Kaplan is, in effect, advocating a more centralized management structure.

decisions" of a traditional management accounting model are optimal "only if the conditions and parameters of the model are assumed to be immutable with respect to managerial actions." As an example, Kaplan cites how Japanese managers "stepped outside the bounds" of the traditional inventory model to ask not "what is the optimal quantity of inventory" but "what conditions do we have to change to eliminate the need to hold any inventory at all." The implication for adoption of flexible automation is that managers may have to step outside traditional accounting systems to make decisions about purchasing, computer-controlled machinery.

Kaplan's work has not gone without comment. In Atkinson & Cummings (1986), Cummings argues that traditional MACS are not being used properly: "if you use numbers without knowing the facts behind them and what the numbers mean, you can make dumb mistakes." Cummings downplays the suggestion that MACS are causing major problems and that they are inappropriate for new technology. He points out that "most people are motivated, not only for this year, but for the next year and the year after that." It is difficult for managers to short-change the future for short-term success because their reputations travel with them. In any case, managers, like other people, are more concerned with security and long-term survival than with short-term success. Cummings agrees with Kaplan that "innovation is something that isn't measured at all by an accounting system," and that this shortcoming can only be overcome by the direct involvement of top management. However, disagreeing with Kaplan, he argues that MACS can actually be a positive force for adaptation to changing environments. For example, in situations where managers are evaluated on the basis of ROI, top management can encourage faster asset replacement by placing higher values on old assets (ie. depreciating them more slowly and marking them up by inflation indices).

Looking at some other works in the accounting literature, McLean (1986) claims that British top management still see manufacturing as a "cost sink" and not as a competitive weapon MACS emphasize cost control and cost savings and do not provide information needed for strategic decisions. Emphasis on accounting measures makes cost avoidance a top priority in manufacturing and forces managers to avoid investing in much needed new technology.

McDonald (1985) says accountants should expand the scope of the criteria used in assessing investments to include strategic benefits He uses the analogy of airplane speed to show how inappropriate criteria can lead to bad decisions Time spent travelling may be a more appropriate criterion than speed when deciding mode of transportation. After factoring in time spent travelling to and from airports and time spent waiting at airports, one might decide to choose train travel over plane travel.

Merchant & Bruns (1986) suggest "different measurements that might lead to a cure for management myopia and selfishness " They first develop criteria for evaluating measurement alternatives and then recommend top management be rewarded "in proportion to the returns realized by the shareholders." They have more difficulty devising performance measures for middle managers and end up proposing a system that combines features of a cash flow system and an economic return system.

The use of discounted cash flow analysis (DCF) has also come under scrutiny in the accounting literature. Primrose et al (1984) defend DCF and say problems caused by poor assumptions and misuse of the technique may be rectified by using the authors' computerized decision-making program

Section II: Empirical Accounting Research

Only one empirical study focuses on the relationship between MACS and the adoption of flexible automation. Woods et al (1985) looked at the capital budgeting procedures of 92 mechanical engineering firms in the U.K. and found significant differences in the investment appraisal methods of adopters and non-adopters of CAD/CAM technology. Table 2.2 shows that non-adopters were more likely to make use of non-financial and "other than DCF/Payback appraisal methods" than adopters. This result appears to contradict the normative literature because it suggests the adoption of advanced technology is positively related to the use of traditional justification methods.

Table 2.2
Use of Investment Appraisal Methods

Method	Adopters Numbers	Adopters Percent	Non-Adopters Numbers	Non-Adopters Percent
Payback	36	57	10	34
DCF	9	14	3	10
Both	7	11	3	10
Non-Financial	4	6	4	14
Other	7	11	6	21
Firms	63	100	29	100

From Woods, Pokorny, Lintner & Blinkhorn (1985)

However, when Woods et al. looked only at adopters and at the appraisal methods specifically used for CAD/CAM systems, they found 37 per cent of the adopters did not calculate "specific costs, expected revenues and depreciated cash flows" in justifying advanced technologies. (See Table 2.3) The authors interpret the results as signifying "a recognition of the limited practical use of formal appraisal methods when dealing with risky or uncertain investments."

Table 2.3
Appraisal Methods for Flexible Automation in Adopters

Method	Numbers	Percent
Payback	16	34
DCF	6	13
Both	1	2
Non-Financial	3	6
Other	4	9
None	17	37
Firms	47	100

From: Woods, Pokorny, Lintner & Blinkhorn (1985)

The Woods et. al. study also found that of 30 firms that used flexible payback periods to evaluate projects, "shortening of payback in response to the risk association with new technology was the single most important reason cited for payback flexibility." This result is unexpected. If anything, one might expect longer payback periods to be positively associated with adoption of flexible automation.[3]

Woods et al. summarize their findings:

> The survey ... shows ... a widespread acknowledgement that risk cannot be dealt with objectively in the context of a capital budgeting system and that instead, firms are more in favour of

[3] The normative literature claims that lowering hurdle rates and increasing length of payback criteria would promote investment in advanced technologies.

subjective judgment and assessment of investment decisions, abandoning formal investment appraisal altogether (p 43)

Two other empirical studies are peripherally related to the thesis topic. Schwarzbach (1985) surveyed 112 manufacturing firms to see if there were any relationships between automation and the way the firms accounted for indirect costs Schwarzbach operationalized "level of automation" by asking the "person most knowledgeable about cost accounting" in each firm to rate level of automation on a single item Respondents were asked to circle a number from 0 to 10, in response to the question "To what extent is your production process now automated?" Sophistication of the accounting system was operationalized by measuring the kind of cost system used, the method of calculating overhead rates and the methods of depreciation Schwarzbach found no demonstrable relationship between level of automation and the "sophistication of the accounting system "

Kaplan (1986b) studied four American firms chosen for being either "leaders in high-technology growth industries or firms in mature industries who were actively promoting productivity and new manufacturing technologies "[4] Kaplan concluded, with some evident surprise, that while the four firms were making dramatic changes in their methods of production, they were not making comparable changes in their "obsolescent" accounting and control systems Elsewhere, Kaplan

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[4] Troberg (1986) employed a similar methodology in his study of European companies and echoed many of Kaplan's conclusions

(1984a) has argued that historically any accounting change that gave its users an economic advantage has been quickly adopted. Given that the four firms chosen for the study were "among the best managed and most successful U.S. corporations," it seems rather peculiar that top management of these firms would waste resources on "obsolescent" systems. Though Kaplan's focus is on MACS and the implementation of advanced technologies, he leaves one wondering about the role of MACS in adoption: Are North American firms adopting flexible automation <u>despite</u> traditional accounting methods, <u>because</u> of traditional accounting methods, or does accounting matter at all?

<u>Section III: Chapter Summary</u>

A basic premise of the widespread literature on MACS and advanced technologies is that traditional accounting methods are inhibiting the adoption of flexible automation. The literature review in this chapter identified those aspects of accounting thought to impact on the adoption of flexible automation. The review showed there is a distressing absence of evidence supporting the existence of any relationship, positive or negative, between characteristics and uses of accounting and adoption of flexible automation. Despite their willingness to declare certain aspects of MACS as anathemas to the process of adoption, there are few authors who offer any realistic and practical alternatives to the criticized practices. Clearly, research is needed to determine which, if any, aspects of MACS are related to the adoption of flexible automation, and how MACS, or practical alternatives to MACS, may be used to support automation strategies. The next chapter describes a methodology for researching some of these issues.

CHAPTER THREE

This chapter is divided into three sections. Section I, which presents the research methodology, is organized around the decisions that were made in developing tests of the hypotheses outlined in Chapter One. Section II describes the data collection process and Section III describes the four groups of automotive part manufacturers chosen for the study.

Section I: Methodology

The four methodological decisions discussed in this section are: the decision to conduct empirical research, the decision to study manufacturers of automotive parts, the decision to sample General Motors of Canada part suppliers, and the decision to use both mail questionnaires and personal interviews to collect data.

I.A. Choosing Empirical Research

As shown in Chapter Two, there is a dearth of empirical research on MACS and adoption of flexible automation. Kaplan (1983, 1986b) and Troberg (1986) urge those who would study MACS and advanced technologies to "leave their offices and study the practices of innovating organizations." Kaplan (1986c) states:

> I too have expressed my concern with the lack of field-based research strategy in management accounting. Major changes in the organization and technology of a firm's operations may be making the accounting and control systems of corporations

> obsolete. Yet these phenomena will go unobserved and unstudied by accounting researchers unless they undertake studies in actual organizations (p. 430).

I agree with these sentiments and therefore decided to study MACS and adoption in "actual" companies. Chapter One has already explained the decision to focus on plant managers and to measure adoption at plant level, so I will now describe the process of selecting a population of plants and plant managers.

I B Choosing a Population

Three criteria were considered in selecting a population of plants that could be used to test the hypotheses

1. To control for "noise," the plants had to be from the same environment. Many factors external to the firm can impact on adoption (Avlonitis & Parkinson 1986, Rogers 1983). It is desirable to control for as many of these factors as possible (Merchant 1981) Typically this is accomplished by choosing a sample of plants from a single large firm (Hopwood 1972, Otley 1978) or from a single industry (Merchant 1981).

2. For the sake of external validity, the plants had to represent a variety of manufacturing processes Adoption of flexible automation may depend on the opportunities for automation presented in a particular manufacturing setting (Cook 1986, Ayres & Miller 1983) For example, the handling of hot metals and heavy loads in a die casting plant might present more opportunities and pressures for adoption of robots than would the handling of cooler, lighter, molded parts in a plastics plant. If the conclusions drawn from this research are to be generalizable, the population of plants had to represent a variety of processes

3. To ensure a fair test of the hypotheses, there had to be some evidence that the population of plants had

some variability in adoption of flexible automation. What was needed was a population where some, but not all, plants were known to have some flexible automation.

I.C.Choosing a Sample of Plants and Managers

The population of Canadian plants that supply parts to automotive assemblers would seem to satisfy the three criteria listed above.[1] The automotive industry is one of only a few that can meet the third criterion: evidence of some variability in levels of adoption. Table 3.1 shows the adoption levels of various flexible automation technologies in the automotive industry as reported in two recent studies. These adoption levels may appear to be low, but the automotive industry leads most other sectors in adoption of advanced technologies (Ontario Centre for Advanced Manufacturing 1986, Economic Council of Canada 1987). For example, 70% of the robots in Canada are installed in plants in the automotive industry (Ontario Ministry of Industry, Trade and Technology 1985).

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[1] Firms that manufacture automotive parts are often described as "second-tiered firms":

> Firms, regardless of size, which have a very limited number of customers and are therefore selling in an oligopsony...The industry sub-set...includes firms that manufacture automotive equipment, accessories, parts, components, supplies, or sub-assemblies but do not assemble these items into complete motor vehicles (Martin 1984, p. 3).

Table 3.1
Flexible Automation Adoption Rates

Technology	% of firms as reported by Automotive Industry Human Resources Task Force (1986)[1]	% of firms as reported by Ontario Centre for Advanced Manufacturing (1986)[2]
Industrial Robots	18%	19%
Programmable Controllers	49%	27%
CNC Machines	18%	37%[3]
Computerized Material Handling	25%	29%
Computer-aided Inspection and Testing	43%	35%
Computer-aided design (CAD)	11%	...[4]
Integration between CAD and Computer-aided Manufacturing (CAD/CAM)	4%	37%

Notes:

1. Percentages taken from raw results supplied by the Automotive Parts Manufacturers' Association of Canada.
2. Reported results are for SIC 37 which includes manufacturers of automobiles, boats and airplanes
3. Combines figures for NC and CNC equipment
4. Not reported

Besides meeting the three formal criteria, the study of plants in the automotive parts industry had two other things to recommend it. The automotive industry is a vital part of the Canadian and American economies and the industry is a bellwether for global competition and technological change.

After a preliminary investigation into creating a sampling frame for the study, it was decided to approach the management of Canada's largest automotive assembler, General Motors of Canada (GMC), and ask for their assistance in identifying and contacting their part suppliers.[2] Managers in the automotive industry are inundated with requests for information from industry, government and academic researchers. A study supported by GMC would likely be better received than an unsponsored study. Limiting the study to GMC suppliers might result in some loss of generalizability but that loss would be offset by the reduction of environmental noise and by the entree offered by GMC.

There are more than 250 suppliers of parts to GMC.[3] As explained later in this chapter, a decision was made to employ a two-wave data collection process: mail questionnaires and personal interviews/plant visits. The requirement to physically visit each plant made it

[2] General Motors of Canada Limited (GMC) is operated as a division of General Motors (GM).

[3] There are more than 400 second-tier parts suppliers in Canada (Automotive Industry Human Resources Task Force 1986). More than half of the second-tiered firms in Canada do some business with GMC.

necessary to select a much smaller sample of GMC part suppliers. The process by which that smaller sample was selected is summarized in Figure 3.1 and described in detail in the following pages.[4]

Figure 3.1
Process of Selecting a Research Sample

400+ Second-Tiered Firms in Canada

|

250+ GMC Part Suppliers

|

51 Plants from Four GMC Product Groups Selected for Study

|

32 Plants and Plant Managers in Final Sample

In consultation with GMC management, I identified 51 plants in four product groups that represented a wide variety of manufacturing processes: metal stampers, plastic molders and finishers, rubber parts manufacturers and functional and decorative die casters. Loosely

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[4] The term "firm" refers to a company with one or more manufacturing plants. To the best of my knowledge, the plants that participated in the study are owned by 32 different firms and thus the term "firm" and "plant" are used interchangeably in this context.

speaking, each group could be called a commodities group. Plants in each group are not necessarily competitors but they do manufacture similar products and employ similar manufacturing processes.[5]

I.C.1. "A Priori" Measures of Adoption and Plant Performance

Before contacting management of the 51 plants, I attempted to answer three questions:

1. Do top managers of the 51 supplier firms support the adoption of flexible automation? Differences in top management preference for flexible automation may be responsible for differences in levels of adoption. Ideally, to control for managerial attitudes towards advanced technology, top management of plants in the sample should support adoption of flexible automation.[6]

2. Do the 51 plants have sufficient variability in adoption of flexible automation? Earlier, I noted that the automotive industry is one of only a few that has invested in flexible automation. If top management of GMC part suppliers generally

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[5] There are no "ready-made" product groupings in the automotive industry. The Automotive Industry Action Group, a voluntary association of assemblers and suppliers, once set up a committee to devise a system of classifying suppliers but after a year of deliberations, the committee gave up on the attempt.

[6] This requirement is consistent with the Chapter One discussion of control and top management/plant manager control dyads.

favour the adoption of flexible automation then most plants in the sample may have similar, high levels of adoption and this cross-sectional study may not be able to distinguish among factors related to adoption. There must be some variability in adoption.

3. **Is there a way of checking for self-selection bias in the final sample?** Empirical research is often criticized for response bias. "successful" firms are thought to be more likely to participate in studies than "less successful" ones. Not all 51 firms invited to take part in the study could be expected to participate and so there should be some check on whether the participating plants differ from non-participating plants on two key measures: adoption of flexible automation and overall performance as GMC part suppliers. Measures of adoption and performance of participants and non-participants would be required to test response bias.

The issues raised by these three questions will be addressed in two parts. First, I will present evidence that top management of GMC part suppliers support the adoption of flexible automation in their firms. Then, I will describe a survey of GMC personnel that provided information on variability of the adoption variable and on response bias.

I.C.2. Goal Congruence in the GM Supplier Network

It is proposed that top management of GMC part suppliers support the adoption of flexible automation. Proof of this assertion would require either a survey of supplier top management or of those who could comment on the attitudes of these managers.[7] Neither option was feasible in the context of the proposed research Therefore, I will provide circumstantial evidence that top management of supplier firms support flexible automation. First, I will show that GM management has stated and implemented a strategy of investment in advanced manufacturing technologies. Next, I will show that this strategy has been communicated to top management of part suppliers and finally, I will argue that it would be to the advantage of current and potential GMC part suppliers to embrace a high-tech manufacturing strategy.

Several studies have examined the automotive industry from global, North American, and Canadian perspectives (Jones 1985, National Academy of Engineering 1982, Regional Industrial Expansion 1983). For all the reasons discussed in Chapter One, these studies have recommended that assemblers and their suppliers invest in state-of-the art manufacturing

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[7] Plant managers should be able to comment on whether their superiors support the adoption of flexible automation and so I asked respondents to agree or disagree with the statement: Top management of this company wants more flexible automation. On a scale of 1=strongly disagree, 3=neutral, and 5=strongly agree, the mean response was 3.5, indicating that top management of the firms in the sample support the adoption of flexible automation. This result confirms the goal congruence argument developed in this section but of course the result was realized only <u>after</u> the survey was conducted.

technologies.[8] GM management has taken the high-tech prescriptions to heart.

Since the early 1980's and his ascension to the Chairmanship of GM, Roger Smith has pursued a high-tech strategy for his company. Smith has been described as the CEO who is "turning GM toward a technological revolution" (Williams & Shultis 1984) and in countless media interviews he has declared that his "deepest passion" is to upgrade GM's technology (Greenwald 1985).

Smith's strategy has been reiterated by other GM top management GM Executive Vice President Lloyd E. Reuss, considered a possible successor to Roger Smith, is quoted in an October 10, 1987, company press release:

> If American business is to meet the global competitive challenges of the future, each company has to "search relentlessly" for new ways to cut lead times, exploit technology and innovate faster [said Reuss]. Mr. Reuss said GM attaches special importance to innovation and technology. "We've made major technological changes at GM already -- and we're going to make a lot more," he said. "A company should not shy away from an aggressive approach to technological innovation ... It's a key element in competing with low wage

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[8] While the cited studies recognize the importance of manufacturing innovations, they note that simply investing in new technologies is not enough:

> Popular accounts of the emergence of Japanese producers as first-rate, worldwide competitors tend to emphasize the impact of the new automation technology (eg. robotics), strong support of the central government..and influence of Japanese culture...There is no doubt that these factors have played some role. Yet, it is our view that the sources of the Japanese advantage are...rooted in a commitment to manufacturing excellence and a strategy that uses manufacturing as a competitive weapon (National Academy of Engineering 1982, pp. 99-100).

> countries ... The end point of competitiveness is products of increasingly high quality and value."

Note that Reuss' statement alludes to many of the competitive advantages of flexible automation that were discussed in Chapter One. Also note the expectation that <u>other</u> companies take a more aggressive approach to technological innovation.

The 1984, 1985 and 1986 <u>General Motors Annual Reports</u> trumpet GM's investments in flexible manufacturing. For example, the 1984 Annual Report has 17 pictures of computer controlled manufacturing technologies including robotic welders, automatic guided vehicle systems, and painting robots. The 1987 Annual reports devotes an entire section to "Investing in the Future: Technological Advancement" and the <u>1987 General Motors Public Interest Report</u> states that from 1980 to 1986, GM invested more than $50 billion (U.S.) in new facilities, tools and equipment.

GM has also upgraded its technology through purchases of several high-tech companies (Electronic Data Systems Corporation and Hughes Aircraft Company) and through joint ventures. An example of the latter is GMF Robotics, a joint venture with Fujitsu Fanuc, a major Japanese manufacturer of industrial robots. GMF has become the biggest U.S. robotics firm. GM is its biggest customer and the world's largest user of robots (Greenwald 1985).

GM management has tried to impart its enthusiasm for advanced manufacturing technologies to parts suppliers. For example, a communication to suppliers to the Buick-Oldsmobile-Cadillac Division (B-O-C), notes that suppliers are expected to "actively institute plans to upgrade technical capabilities and adopt new and appropriate technologies" and "to remain abreast of state-of-the-art technology for the commodities they produce" (B-O-C Document 1986). And in meetings with supplier top management, GM management has hammered home the need to utilize advanced manufacturing technologies (General Motors of Canada 1986).

Through its media interviews and public announcements, through its actions, and through its direct communications with suppliers, GM management has clearly and consistently stated its commitment to flexible automation. Because of several industry trends, the GM automation strategy would be expected to be endorsed by part supplier management. One such trend is increased outsourcing. North American automakers are retreating from vertical integration and making ever larger purchases of parts and assembled components from outside suppliers (Flynn 1987). It has been estimated that by the mid 1990's, GM will be sourcing 60% to 70% of its parts from outside suppliers (Courtis 1986). The prospect of winning new business from GM would be an incentive for parts suppliers to try please GM.

Just-in-time delivery, single-sourcing and long-term contracts between assemblers and suppliers are other trends that put pressure on suppliers to conform to the demands, expectations and norms of their customers (Jones 1985, Regional Industrial Expansion 1983). Given GM's emphasis on a technological strategy, and given the forces pushing suppliers towards congruence with GM objectives, one would expect top management of supplier firms to support investments in new technology, if for no other reason than to please a major customer.[9]

I.C.3. **Measures of Adoption Variability and Response Bias**

To check for response bias and for variability in adoption, I asked 26 GMC purchasing, quality assurance and engineering personnel to rate the 51 suppliers on several criteria. Table 3.2 shows the general format of the questionnaire given to each GMC respondent. The first four items in Table 3.2 are used to assess the supplier firms on adoption of advanced technologies and the last two items are measures of overall performance.

[9] When asked why their firms were adopting flexible automation, many of the plant managers in the study said it was to meet customer expectations. This finding is discussed in greater detail in Chapter Six.

Table 3.2
Items in Survey of GMC Personnel

In your opinion, compared to its competitors, the FIRM NAME plant's...

	Worst	Below Average	Average	Above Average	Best
investment in new machinery and equipment is	1	2	3	4	5
use of state-of-the-art production equipment is	1	2	3	4	5
use of robots, CAD/CAM and other flexible manufacturing technologies is	1	2	3	4	5
use of computers in manufacturing is	1	2	3	4	5
overall performance as supplier to GM is	1	2	3	4	5
chances of being a GM supplier five years from now is	1	2	3	4	5

Table 3.3 presents each plant's mean score on the GMC measures of adoption of automation and of performance, along with the number of raters who evaluated each plant. Since GMC personnel were asked to rate only those plants, and only on those criteria with which they were familiar, the number of raters for each plant and for each variable differs. "Automation" is the mean score on the four advanced technology items listed in Table 3.2, and "performance" is the mean

score on the "overall performance" and "future chances" items.[10] The GMC ratings will be used later in this chapter to test for self-selection bias, but at this point, they will be used to check for variance in levels of adoption of flexible automation.

The plant scores on the GMC measures of adoption of automation ranged from 2.00 to 4.47, with a mean of 3.22 and a standard deviation of .52 The GMC raters indicated that 16 of the 51 firms had "below average" flexible automation. These statistics would evince that, from the perspective of GMC personnel, there is variability in adoption: some of the firms in the sample are, and others are not, adopting flexible automation.

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[10] Because each score is the mean of two or more items, scores on adoption and performance may not be integers even when there is only one rater. For example, a single rater may have scored a plant as a "3" on overall performance and a "4" on chances of being a GM supplier five years from now. In this case the performance score in Table 3.3 would be "3.5".

[redacted]

Table 3.3
GMC Personnel Survey Results

Plant ID (Group 1)	Number of Automation Raters	Mean of Scores on Automation	Number of Performance Raters	Mean of Scores on Performance
1	6	3.38	7	4.00
2	5	3.67	7	3.93
3	6	3.17	7	3.57
4	6	3.08	7	3.79
5	4	3.50	5	4.10
6	6	2.39	9	2.56
7	5	2.95	6	3.67
8	6	2.71	8	3.44
9	5	4.20	6	4.17
10	7	3.36	8	3.38
11	3	3.25	3	2.83
12	7	3.36	9	3.44
13	4	2.75	6	3.50

Plant ID (Group 2)	Number of Automation Raters	Mean of Scores on Automation	Number of Performance Raters	Mean of Scores on Performance
14	1	3.25	2	3.25
15	1	2.50	1	3.00
16	2	2.13	3	3.00
17	2	3.50	3	3.67
18	2	3.00	3	3.17
19	1	2.50	1	3.00
20	3	3.25	4	3.13
21	-	-	1	4.00
22	1	2.50	1	3.00
23	2	4.38	2	3.50
24	1	2.00	1	3.00
25	3	2.92	3	3.33
26	2	2.75	3	3.00
27	2	2.63	2	4.00
28	2	4.13	2	3.50

Continued...

Table 3.3 (Continued)
GMC Personnel Survey Results

Plant ID (Group 3)	Number of Automation Raters	Mean of Scores on Automation	Number of Performance Raters	Mean of Scores on Performance
29	4	3.50	4	3.88
30	5	3.35	5	4.10
31	4	3.50	4	4.00
32	4	3.31	5	3.90
33	4	3.44	5	3.70
34	2	3.75	2	3.25
35	3	3.44	3	4.00
36	4	2.56	4	2.38
37	4	3.69	4	3.75
38	4	2.75	4	3.25
39	5	4.10	5	3.80
40	2	2.75	2	3.25
41	3	2.83	3	3.50

Plant ID (Group 4)	Number of Automation Raters	Mean of Scores on Automation	Number of Performance Raters	Mean of Scores on Performance
42	5	3.55	5	3.70
43	1	2.50	1	3.00
44	2	3.25	2	3.00
45	3	3.33	3	4.00
46	3	3.08	3	3.67
47	3	3.42	3	4.17
48	5	3.45	5	3.60
49	3	3.33	3	3.00
50	4	3.13	4	3.75
51	4	4.06	4	3.88

[redacted]

I.D. Choosing a Data Collection Method

As indicated earlier, this study collected data in two ways: plant managers were sent mail questionnaires and after the questionnaires were returned, managers were interviewed and their plants inspected.

There were several reasons for deciding to use a two-wave methodology. To begin with, many of the key variables in Models A and B could be measured with both mail and interview instruments. Since personal interviews would be conducted several weeks after the completion of mail questionnaires, I expected to get estimates of measurement validity across method and time. There were also some motivational considerations: plant managers would be more likely to return their mail questionnaires knowing I would visit them.[11] Finally, and perhaps most importantly, I was persuaded by the argument that "the external validity [of mail surveys] to be far too low for understanding management accounting phenomena" (Kaplan 1986c). By employing self-administered questionnaires and field visits I expected to get a more complete and accurate picture of the role of MACS in the adoption of flexible automation.

Section II: Surveying Suppliers

The Director of Purchasing for GMC sent top management of each of the 51 firms a personal invitation to participate in the study. Appendix B shows a copy of the letter of invitation, and the accompanying information and response sheets. Thirty-two or 63% of the firms agreed to participate in the study. I contacted as many of the non-participants as possible to find out why they had decided not to participate. The most often cited reason was plant manager

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[11] All 32 plant managers in the final sample returned their mail questionnaires.

unavailability. In one case, the plant manager had recently retired and a new manager had not yet been appointed. In another case, the plant manager was in hospital. In several instances the plant manager was said to be too busy to participate. And finally, one supplier did not participate in the study because the firm was in the process of being sold.

II.A.Tests of Self-Selection Bias

There is no evidence of self-selection bias in the final sample of 32 plants. The mean of the GMC personnel survey automation scores of the participating plants was 3.20 and of the non-participating plants, 3.25. A two-tailed t test of means showed no significant difference between participants and non-participants on this "a priori" measure of adoption of automation ($p=.74$). A similar test on the means of the GMC survey performance scores of the participating plants (3.47) and non-participating plants (3.56) also showed no significant difference between the two groups ($p=.51$).

To check if participation was independent of product group, I performed a Chi-square Test of the contingency table shown in Table 3.4 and found participation in the study was independent of membership in product group ($p=.85$).

Table 3.4
Participation by Group

	Declined to Participate	Agreed to Participate	Totals
Group 1 Stampers	6	7	13
Group 2 Plastics	5	10	15
Group 3 Rubber	4	9	13
Group 4 Die Casters	4	6	10
Total	19	32	51

To sum up, on the key variables of automation and performance, the 32 participating plants are representative of the 51 plants in the sampling frame.

II.B.Data Collection Procedures

Table 3.5 summarizes the steps followed in collecting data for the study. I have already described the survey of GMC personnel and the invitations sent to the suppliers, and will now describe the mail and personal interview surveys of the plant managers.

Table 3.5
Data Collection Process

1. Self-Administered Questionnaires Completed by GMC Raters
2. Invitations to 51 Firms to Participate in Study
3. Self-Administered Questionnaires to 32 Plant Managers
4. Face-to-face Interviews with 29 Plant Managers
5. Tours of 24 Plants

When a supplier returned a response sheet and agreed to participate in the study, I sent out a package to the person identified as plant manager. Each package included a cover letter, instructions and a questionnaire. Copies of the cover letter and instruction sheet are presented in Appendix C. The questionnaire itself is described in Chapter Four. Mail questionnaires were typically followed by face-to-face interviews of plant managers and tours of their plants. In two instances, mail questionnaires were completed after the face-to-face interviews. In these situations, the interview protocol, which is also described in Chapter Four, was slightly altered to prevent contamination of the written questionnaire.

From initiation of the survey of GMC personnel to completion of the plant visits, the data collection process stretched out over six months.[12] All 32 managers in the final sample returned mail questionnaires, 29 managers were interviewed, and 24 facilities were inspected. Three of the managers who had returned mail questionnaires were not interviewed for the following reasons: top management of one of the supplier firms gave permission for the plant manager to participate in the mail questionnaire but asked that he not be interviewed, one manager left his job shortly after he returned the questionnaire, and one manager would not commit himself to an interview even after six calls Five of the interview sessions were not followed by plant tours for the following reasons: in three instances the personal interviews took more than 2 hours to complete and the plant managers did not have time to conduct plant tours, and in the other two cases the firms had policies that restricted plant tours.

The plants in the sample were scattered along a 1,500 km corridor between Montreal (Quebec) and Windsor (Ontario). Whenever possible, I tried to arrange visits to several plants in the same vicinity. Typically, I would visit two plants in one day and spend 2.5 hours at each plant. Half the time would be spent interviewing the manager and the other half touring the plant. The personal interviews and plant tours were conducted over a seven week period from late August to mid-October, 1987.

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[12] During those six months there were two postal strikes, each occurring at critical stages of the data collection process. Courier services minimized the problems caused by the strikes.

Chapter Four will detail the items in the self-administered questionnaire and the protocol for the face-to-face interviews. Before proceeding with the description of the survey instruments, I will present notes on each of the four supplier groups in the sample.

Section III: The Four Supplier Groups

This section describes general characteristics and manufacturing processes of the four product groups in the sample. At the time of the study, GMC made most of its major mechanical components in-house and relied on external suppliers for the production of smaller, mostly decorative parts. Suppliers in the study manufactured parts ranging in value from a few cents, for small rubber or plastic molded parts, to over $150 for assembled components.

The four product groups represent a wide variety of processes (mixing, molding, machining, extruding, cutting, painting, plating, assembling) and materials (aluminum, magnesium, steel, brass, fabrics, a variety of plastics and rubbers). The groups also represent different stages of the product lifecycle and different competitive strategies. Stampers were in a mature phase of the product lifecycle. Plants were operated as "cash cows," machinery was old, and cost cutting was emphasized. In contrast, plastic molders and metal die casters were in the growth phase of the product lifecycle. Sales were increasing, emphasis was on product and process innovation, and machinery was newer. Plants in the rubber group were so diverse in product and process that no generalization is possible. More specific descriptions of each group follow.

III.A.Group 1 - Metal Stampers

In a characteristic metal stamping plant, metal blanks were cut from large rolls of thin steel strips. The blanks were stamped into shape by large metal presses and the stamped parts were cleaned and then, in some cases, painted, machined or assembled (welded) into larger components. The stamping process was noisy and sometimes dangerous The presses were usually more than ten years old but were well maintained and had been upgraded with some automated features and safety add-ons. Compared to other parts, dimensional tolerances for stamped parts are not high, though visible parts (such as bumpers) must meet high appearance standards. To reduce costs and assembly work, efforts were being made to redesign parts. For example, rather than stamping two bumper components and then welding them together, some plants were stamping one-piece bumpers.

III.B.Group 2 - Plastic Molders and Finishers

Many of the plants in this group molded and finished plastic parts, but some plants specialized in finishing. I will discuss molding first.

There are two basic types of plastic molding. In thermoplastic molding, the raw material is mixed in advance and injected into a mold where heat and pressure form the plastic part. In reaction-injection molding, two or more different materials are injected into a mold where they undergo a chemical reaction. Thermoplastic molding is a more forgiving process: materials in scrap and spoilage can be recovered. Important to both processes is control of factors such as temperature, humidity, and time in mold. And in both process, the molded part must be deflashed. That is, excess materials must be trimmed from the part after it is removed from the mold.

Plastic finishing includes painting, metal-plating, and assembling It is difficult to paint or plate plastic products One reason is that plastics cannot tolerate high temperatures, and many of the painting and plating processes require coatings to be "baked" onto the part. Painting and plating problems are compounded by the fact that finished plastics are "visible" parts and are expected to have flawless surfaces.

A trend particularly evident in the plastics group was the assembly of parts into modules or systems. For example, rather than shipping a number of small signal light components to GMC, some plants were manufacturing and assembling complete signal light housings. An important issue for firms in the plastics group was coordinating production and assembly of several parts within the same plant and among sister plants.

III C.Group 3 - Rubber Parts Manufacturers

Plants in this group manufactured a wide range of products: tires, gaskets, floor mats, tubing, and weather-stripping Most plants mixed their own rubber compounds and then molded (engine mountings), pressed (tires and floor mats) or extruded (door side-moldings) the mixture into a final form. Rubber molding and pressing processes are similar to plastic molding and metal stamping respectively. In the extrusion process, soft rubber is forced through a die in a continuous process and cut off in required lengths. Like plastic parts, most rubber parts must be deflashed, but unlike most plastics, rubber must be cured. If plastic molding is a science, making rubber parts is an art. Rubber manufacturers were reluctant to talk about their art lest they revealed the secrets of their rubber recipes and curing processes.

III.D.Group 4 - Decorative and Functional Die Casters

In a characteristic die casting plant, a metal (usually aluminum) was melted and the molten metal ladled into a mold. Molded parts were cooled and deflashed and then sometimes machined or assembled. Some of the die casting plants had unpleasant and dangerous environments.

The main difference between functional and decorative die cast parts is that the former must meet certain critical dimensional tolerances while the latter must also meet high appearance standards. A transmission housing is an example of a functional casting and a door handle a decorative casting.

III.E. Opportunities for Automation

Virtually every process employed by plants in the four groups can be automated. To take plastics as an example, computer-operated equipment can be used to: mix plastic resins, place the resins in molds, control the molding process (heat, pressure, time-in mold), remove parts from molds, deflash parts, paint parts, assemble several parts together and test finished components. Different plants, even those within the same group and producing the same product, used automation differently. Things done by robot in one plant were being done manually in another plant and vice versa. However, I can make some generalizations about adoption of flexible automation across the four groups.

In all four groups, computers were being used to test product quality. While sophistication of computerized inspection and testing equipment varied, almost all plants had achieved some computerization in this area.[13] Molding of plastic, rubber and metal was another area that was becoming increasingly automated because equipment manufacturers were automating molding machines. However, while plastic molders and metal die casters were making increased use of robots to remove parts from molds, this function had proved to be more difficult to automate

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[13] To help meet high quality standards, North American automotive assemblers have demanded their suppliers adopt computerized inspection and testing equipment.

in rubber plants. Finally, one process that was a high priority for automation in every group was painting. Automating the painting process increased the consistency of the procedure and protected workers' health.

CHAPTER FOUR

This chapter explains the operationalization of the constructs in Model A (relationships between MACS and adoption) and Model B (relationships between MACS and adoption with controls for decentralization), and a number of other constructs that were considered in the evaluation of those models. The chapter is divided into three sections. Section I presents the mail questionnaire items, Section II discusses the protocol and codings of the face-to-face interviews, and Section III summarizes the chapter.

Table 4.1 lists the main variables used to test the Model A and B Hypotheses. Other variables that are referred to in Chapters Five and Six are listed in Table 4.12 and in Appendices D and E.

As shown in Table 4.1, each of the oonstructs in Models A and B have been given a label:

EMFEVL	is emphasis on accounting measures for evaluation of managerial performance
TMHOR	is time horizon of the MACS
EMFJST	is emphasis on financial criteria in justifying investments in flexible automation
DIFQUN	is difficulty in quantifying automation benefits in accounting terms
DECENT	is degree to which lower levels of a firm participate in decision-making and control own work

ADOPT is level of adoption of flexible automation

The instruments used to tap the constructs are identified by labels and by numeric and alphabetic suffixes. The numeric suffixes differentiate among measures of a construct. In some cases, multiple measures are indicated because there is more than one established instrument associated with a construct. In other cases, the use of several measures reflects the multidimensionality of a construct. The alphabetic suffixes refer to method of data collection:

G - indicates a variable from the survey of General Motors of Canada (GMC) personnel

M - indicates a variable from the Mail survey of plant managers

F - indicates a variable from the Face-to-face interviews of plant managers

Thus, ADOP1M refers to a mail questionnaire measure of adoption and ADOP2M refers to a different mail questionnaire measure of adoption. ADOP2G is the same instrument as ADOP2M, but whereas ADOP2M is a plant manager mail survey measure, ADOP2G is a GMC personnel survey measure. And, as will be explained later, ADOP4FM is a ratio with a numerator from the face-to-face interviews and a denominator from the mail questionnaires.

In Table 4.1, the numbers under the heading "Table" refer to the tables in this chapter which depict the mail questionnaire items. The face-to-face variables are registered in Appendix D (Interview Protocol) and Appendix E (Interview Coding Sheet).

The references listed under "Sources" in Table 4.1 specify versions of the instruments used in the study. For example, DECENT2M is a measure of decentralization suggested by Hage & Aiken (1967) and refined by Dewar et al. (1980). Only Dewar et al. are cited in Table 4.1 because their version of the instrument is used in the study. Measures specifically designed for this study, are indicated as being "New."

The number of items in each measure and the procedure used to generate a scale from the items is indicated under the Table 4.1 heading, "Scale/Items." In most cases, variables were created by summing the scores on the items of a measure. The number of items, possible scores on each item, and the procedure used to generate a scale, determine the range of each measure as reported in the last column of Table 4.1. For example, EMFEVL2M has four items and each item can have a score between 1 and 5 inclusive. Since EMFEVL2M is the sum of the scores on the four items, the variable can range between 4 and 20.

[redacted]

Table 4.1
Main Variables in Models A and B

Construct Name and Definition	Table	Instrument Name and Source	Scale Items	Range
EMFEVL emphasis on accounting measures for performance evaluations	4.2	EMFEVL1M Brownell & Hirst (1986)	C* 1	1-4
	-	EMFEVL1F Interview version of EMFEVL1M	C 1	1-4
	4.3	EMFEVL2M Merchant (1981)	S 4	4-20
	4.4	EMFEVL3M Merchant (1981)	S 10	10-50
TMHOR time horizon of accounting measures	4.5	TMHOR1M New	S 3	3-20
	4.5	TMHOR2M New	S 3	3-20
	4.6	TMHOR3M Cook (1986)	A 1	Open
	-	TMHOR3F Interview version of TMHOR3M	A 1	Open
EMFJST emphasis on financial criteria in justification	4.7	EMFJST1M New	S 4	4-20
	-	EMFJST2F New	C 1	0-2
DIFQUN difficulty in quantification	4.8	DIFQUN1M New	S 6	6-30
DECENT decentral-ization	4.9	DECENT1M Schroeder (1981) Marshall (1985)	S 15	15-75
	4.10	DECENT2M Dewar et al. (1980)	S 5	5-20

* C-coded response, S-sum of items, A-actual response, M-mean of items

Continued...

Table 4.1 (Continued)
Main Variables in Models A and B

Construct Name and Definition	Table	Instrument Name and Source	Scale Items	Range
ADOP adoption of flexible automation technologies at plant level	4.11	ADOP1M Cook (1986) Several industry surveys	S* 8	8-32
	3.2	ADOP2M New	M 4	1-5
	3.2	ADOP2G GMC survey version of ADOP2G	M 4	1-5
	-	ADOP3F Cohn & Turyn (1984)	A 8	Open
	-	ADOP4FM Created by dividing ADOP3F by number of plant workers	- -	-
	-	ADOP5F New	C 1	1-5

* C=coded response, S=sum of items, A=actual response, M=mean of items

[redacted]

The mail questionnaire and the interview protocol were critiqued by several colleagues', but for the following four reasons, it was thought unnecessary to pretest the instruments on a sample of plant managers. First, many of the instruments used in the study have been tested and used in previous studies. Second, respondents to the mail questionnaire were encouraged to seek clarification of confusing items at the follow-up meeting with the researcher. Third, because of the length of time between mail questionnaire responses and face-to-face interviews, mail questionnaire data could be analyzed, shortcomings identified, and problems addressed in the follow-up interviews. Finally, conducting a pre-test on even a small fraction of the sample would have severely reduced the power of the statistical tests used to test the hypotheses.

Section I: The Mail Questionnaire

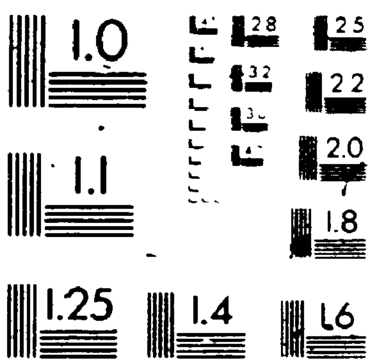
In Chapter Three, I described the procedures followed in administering the mail questionnaire to the 32 plant managers. Copies of the introductory letter and instruction sheet that accompanied each questionnaire are shown in Appendix C. In this section, I will present the actual mail questionnaire instruments.

I.A: EMFEVL (EMphasis on accounting For EVaLuation)

There are three mail questionnaire measures of EMFEVL: EMFEVL1M, EMFEVL2M and EMFEVL3M.

EMFEVL1M is Hopwood's (1972) measure of supervisor evaluation style. Hopwood gave cost centre heads of a large manufacturing firm lists of eight criteria that might be used to evaluate their performance. He asked respondents: "What do you think counts the most in how your departmental supervisor evaluates your performance?" Among the criteria were "concern with costs" and "meeting the budget." Hopwood (1972) classified evaluation style into four categories:

2



1. Nonaccounting style:	neither meeting the budget nor concern with costs ranked among the top three criteria.
2. Profit Conscious style:	concern with costs, but not meeting the budget, ranked among the top three criteria.
3. Budget-Profit style:	both meeting the budget and concern with costs among the top three criteria
4. Budget Constrained style	meeting the budget, but not concern with costs, ranked among the top three criteria.

There is an implied ordinal scale underlying this classifications scheme, with Budget Constrained style at one end of the scale and Nonaccounting style at the other (Otley 1978). In a Budget Constrained situation, accounting measures of performance influence all aspects of the behaviour of a manager and his/her supervisor. In a Profit Conscious situation, managers and their superiors use accounting measures for problem-solving, and managers are evaluated on financial and non-financial criteria. In a Nonaccounting situation managers are evaluated on non-financial criteria.

Hopwood's measure has been used by Otley (1978), Brownell (1982), Brownell & Hirst (1986) and Govindarajan (1987). For this study, I slightly modified the Brownell & Hirst (1986) version. Because I was dealing with a number of different companies and could not be sure of the completeness of the list of criteria, I added a line for respondents to write in criteria not included in the question. I also changed the item "cooperation with individuals outside the firm" to read "keeping customers happy." Table 4.2 presents the final form of the measure.

The coding of responses to EMFEVL1M follows Hopwood (1973), except that instead of coding the top three criteria in each response, I followed Brownell & Hirst (1986) and coded the top four. The inclusion of the fourth ranked criterion in the coding is justified by the increase in the number of criteria considered (Brownell & Hirst 1986). To illustrate, if a respondent ranked budget but not cost as one of the four most important criteria in his evaluation, his response would be classified in the Budget Constrained category and be coded as a "4." A score of "3" indicates a Profit-Budget Style, a "2" is a Profit Style and a "1" is a Nonaccounting Style. A higher score on EMFEVL1M indicates that a plant manager's supervisor places more emphasis on accounting measures in the evaluation of the manager's performance.

Table 4.2
EMFEVL1M

What do you think counts the most in how your boss evaluates your performance?

Put the number 1 next to the item you think counts the most.
Put the number 2 next to the item that counts second most
Put the number 3 next to the item that counts third most.
Finally, put the number 4 next to the item that counts fourth most.

___ How well you cooperate with co-workers

___ Your concern with costs.

___ How well you get along with your boss.

___ How much effort you put into your job.

___ Your concern with quality.

___ Meeting the budget.

___ Your attitude toward your work.

___ Your attitude toward your company.

___ Your ability toward your company.

___ Your ability to handle your co-workers.

___ Your ability to keep your customers happy.

___ Other ______________________________.

There are two problems with EMFEVL1M. The first problem is interpreting the Nonaccounting Style. Forty-four percent of the subjects in Hopwood's (1972) study were classified in the Nonaccounting category. Hopwood dropped this group from his analysis but did so with some trepidation:

> It is possible that in at least some of the so-called Nonaccounting evaluations, the accounting data may represent an important means of-feedback to a cost centre head, influencing his self-evaluation and subsequent behaviour even though they are relatively unimportant in his superior's evaluation (p.177).

The point is that even when financial results are not directly tied to the performance measurement and reward system, they may be used by managers themselves to evaluate their performance and the performance of their peers, and by top managers to select people for promotion (Banks & Wheelwright 1979). A second problem with the Hopwood measure is that it employs only a single item and thus precludes estimation of measurement error. These two problems have been addressed by the addition of two other measures, EMFEVL2M and EMFEVL3M, from Merchant (1981).

The 4 item, EMFEVL2M, was employed by Swieringa & Moncur (1972) and by Merchant (1981) to measure the extent to which managers are required to explain budget variances to their superiors. It is thought that managers who have to explain their budget performance to supervisors experience more pressure to achieve budget targets (Carruth & McClendon 1984). See Table 4.3 for the EMFEVL2M instrument.

Table 4.3
EMFEVL2M

Listed below are a number of activities related to your job and use of budgeting. Please indicate how often each activity takes place.

	Never	Rarely	Sometimes	Often	Always
I am required to submit an explanation in writing about causes of large budget variances	1	2	3	4	5
I am required to report actions I take to correct causes of budget variances..	1	2	3	4	5
I am required to prepare reports comparing actual results with budget.........	1	2	3	4	5
I am required to trace the cause of budget variances to groups or individuals within my plant.............	1	2	3	4	5

The 10 items in EMFEVL3M measure extrinsic and intrinsic motivation to score well on accounting measures of performance (Hackman & Porter 1968, Dermer 1975, Merchant 1981). The first 7 items in EMFEVL3M measure the extent to which budgeting systems are linked to corporate rewards and the last 3 items measure the extent to which budget performance is linked to personal satisfaction. I justify combining the extrinsic motivation measure with measure of intrinsic motivation because Dermer (1975) concluded the two constructs are corequisites and because the Spearman Rank-Order Correlation between the two scales is .70 ($p<.01$) in Merchant (1981). Table 4.4 presents the 10 Likert-type items of EMFEVL3M.

Table 4.4
EMFEVL3M

Please circle one number for each of the following statements about budgets and budgeting in your company.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Budget performance is an important factor in advancing my career.....	1	2	3	4	5
If I exceed budget targets I will get more responsibility........	1	2	3	4	5
My job security will improve if I consistently meet budget targets.......	1	2	3	4	5
My pay increases are closely tied to budget performance.	1	2	3	4	5
My talents will be better recognized if I meet my budget targets............	1	2	3	4	5
I will have better relations with my boss if I perform well in relation to the budget..	1	2	3	4	5
Other managers will think more highly of me if I perform well in relation to the budget.............	1	2	3	4	5
I get a great sense of personal satisfaction when my performance compares favorably with the budget..	1	2	3	4	5
Good performance on budget targets gives me a feeling of accomplishment..........	1	2	3	4	5
Managing to achieve budget targets contributes to my personal growth and development................	1	2	3	4	5

I.B.TMHOR (TiMe HORizon of accounting system)

Three mail questionnaire items measure TMHOR. TMHOR1M and TMHOR2M deal with the time horizons of performance measurement and reward systems, while TMHOR3M measures the payback criteria used to screen capital budgeting proposals. I will first discuss TMHOR1M and TMHOR2M, and then TMHOR3M.

Lorsch & Morse (1974) used a four item instrument to measure the "time dimension of formal practices." They asked respondents to indicate the time span of their business unit's formal performance review, the time span of its shortest reporting period, the range of time over which its employees could commit resources and its throughput time. Calling the construct "information detail," He[illegible] (1981) used a similar instrument to measure the smallest block of time for which accounting reports are prepared. In this study, I asked respondents to indicate the time spans of budget targets, budget reports, and formal reviews of performance. Because firms typically have multiple targets, reports and performance reviews, I asked respondents to indicate the time periods of all targets, reports and formal reviews. To give managers a focus for their responses, I defined budget targets and reports. Table 4.5 shows the three items in TMHOR1M and TMHOR2M. The lowest numbered response to each of the three items were summed to form the TMHOR1M variable and the highest numbered response to each of the three items were summed to form TMHOR2M.[1] Thus, TMHOR1M and TMHOR2M may be interpreted respectively as measures of the short-term and long-term time horizons of the MACS.

[1] If only one number was circled for any response, that number was used for both TMHOR1M and TMHOR2M. Respondents who did not have budget targets, reports or formal evaluations were not included in the TMHOR1M and TMHOR2M analyses. However, as discussed later, the adoption levels of these respondents were investigated.

Table 4.5
TMHOR1M and TMHOR2M

Budget targets are cost, sales, profit and/or return on investment goals set for your plant. For which of the following time periods do you have budget targets? (Circle more than one number if appropriate.)

1 Daily budget targets.
2 Weekly budget targets.
3 Monthly budget targets.
4 Quarterly budget targets (ie. targets for each three month period).
5 Annual budget targets.
6 Budget targets for periods longer than one year.
7 Do not have any budget targets.

Budget reports are statements of costs, sales, profits, return on investment and/or variances from budget targets. Which of the following types of budget reports do you have for your plant? (Circle more than one number if appropriate.)

1 Daily budget reports.
2 Weekly budget reports.
3 Monthly budget reports.
4 Quarterly budget reports.
5 Yearly budget reports.
6 Long range budget reports.
7 Budget reports for each project or contract.
8 No budget reports.

How often do you receive a formal review of your performance? (Circle more than one number if appropriate.)

1 Daily review of performance.
2 Weekly review of performance.
3 Monthly review of performance.
4 Quarterly review of performance.
5 Annual review of performance.
6 Formal review of performance occurs less than once a year.
7 Formal reviews for each project or contract.
8 No formal review of performance.

TMHOR3M represents the implicit time dimension of the capital budgeting process. Thomsen (1984) argues that with high discount rates "the distant future has practically no significance to the decision-maker who uses present value calculations." A similar argument can be made for payback criteria (Pike 1983). Higher hurdle rates and shorter required paybacks for proposed investments are expected to shorten managers' time horizons.

The items in Table 4.6 were adapted from Cook (1986). Interestingly, almost every manager indicated that capital investments were not required to meet rate of return or hurdle rate criteria. This result was confirmed in the face-to-face interviews. Plant managers were not using discounted cash flow methods to analyze projects. Though, in some cases, more sophisticated methods were used by corporate level staff, plant managers themselves used only payback criteria to assess potential investments.[2] Therefore, only the two payback items of Table 4.6 are relevant to this study. When managers indicated they used different payback criteria for investments in flexible automation, that response was used. Otherwise, TMHOR3M represents the "all purpose" payback criterion.[3]

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[2] In many cases plant managers were unfamiliar with the discounted cash flow technique and had no idea if anyone in their firm used the technique. In the few cases where managers were familiar with the technique and knew that "someone at head office" calculated each proposal's net present value or internal rate of return, they did not know or would not say what the discount or hurdle rate was.

[3] As discussed in Chapter Two, Woods et al. (1985) found that some firms used one set of criteria and evaluation technique for assessing investments in regular equipment and another set for advanced technologies.

Table 4.6
TMHOR3M

Are capital investments in your plant required to exceed a certain rate of return or hurdle rate? (Circle number.)

1 Yes ---> What is the hurdle rate? _____%

2 No ---> (Please skip next question.)

Are some capital investments in flexible automation required to meet a different hurdle rate than other investments? (Circle number.)

1 Yes ---> What is the hurdle rate for flexible automation? _____%

2 No

Is there a required payback period for capital investments in your plant? (Circle number.)

1 Yes ---> What is the required payback? _____ years

2 No ---> (Please skip next question.)

Are some capital investments in flexible automation required to meet a different payback period than other investments? (Circle number.)

1 Yes ---> What is the required payback for flexible automation? _____ years.

2 No

I.C.EMFJST (EMphasis on Financial JuSTification of automation)

I.D.DIFQUN (DIFficulty in QUaNtifying benefits of automation)

There are no established measures for EMFJST and DIFQUN, so instruments were developed to tap these two constructs. The measure, EMFJST1M, displayed in Table 4.7, asks respondents to agree or disagree to four statements declaring that approval of investments in new equipment depends on financial issues. DIFQUN1M is a six item instrument that asks respondents their opinion on how difficult it is to estimate the dollar value of automation benefits and the extent to which automation costs are easier to estimate than benefits. DIFQUN1M is presented in Table 4.8. Scores on the first item of DIFQUN1M were reversed.

The items in EMFJST1M and DIFQUN1M reflect issues raised in the literature reviewed in Chapter Two. Because these measures are new, special effort was made in the face-to-face interviews to get a sense of the importance of financial justification to the approval of flexible automation projects and the difficulty in quantifying automation proposals in financial terms.

Table 4.7
EMFJSTIM

Here are some statements about buying new machinery and equipment. Please circle one number for each statement.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I can get new equipment only if I can convince my superiors that the investment makes financial sense	1	2	3	4	5
When it comes to new technology, the only thing top management wants to know is "How much will it cost?"	1	2	3	4	5
Plant performance is measured by return-on-investment	1	2	3	4	5
Managers who want new equipment are expected to be able to show that the equipment will increase profits	1	2	3	4	5

Table 4.8
DIFQUNIM

Here are some statements about estimating the costs and benefits of flexible automation. Think of the situation in your company when you circle one number for each statement.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
It would be easy to estimate the benefits of flexible automation in dollars	1	2	3	4	5
If you play around with cost and revenue estimates, you can make any investment in new equipment look good	1	2	3	4	5
It would be hard to estimate the costs of flexible automation	1	2	3	4	5
Usually, top management is suspicious of estimates of the financial <u>benefits</u> in proposals to buy new equipment	1	2	3	4	5
There is lots of flexibility in what costs and benefits can be included in a proposal to invest in new equipment	1	2	3	4	5
Top management expects managers to underestimate the costs of investments in new equipment	1	2	3	4	5

I.E.DECENT (DECENTralization)

Centralization has been defined as the "extent to which the locus of authority to make decisions affecting the organization is confined to the higher levels of the hierarchy" (Child 1973). The construct "centralization" and its complement, "decentralization" have figured prominently in both innovation and accounting literatures. For the sake of consistency, I will use the term "decentralization" rather than "centralization," recognizing that the terms represent opposite ends of the same scale.[4]

Three different measures of decentralization were considered for this study. Accounting researchers have typically used the abbreviated Aston measures (Pugh et al. 1968, Inkson et al. 1970), while many innovation researchers have employed the Aiken & Hage instruments (Dewar et al. 1980). Recently, several innovation studies have used a "key informant type of methodology" (Marshall 1985). I will discuss each of these three measures of decentralization.

The Aston instrument presents subjects with a list of 23 standard decisions and asks them to indicate the level of the organization at which those decisions are made. Variations of the Aston measure have been used by Bruns & Waterhouse (1975), Merchant (1981) and Chenhall & Morris (1986). The Aston instrument was thought to be inappropriate

[4] To restate Child (1973), decentralization is defined as the extent to which the locus of authority to make decisions affecting the organization is confined to lower levels of the hierarchy.

for this study because few of the 23 standard decisions relate to the investment decision per se. As well, because of the variety of firms in the sample, it would be difficult to construct meaningful labels for equivalent hierarchical levels at which decisions are made.

In the key informant instrument, respondents are presented with a list of common activities and asked to state the level of the organization responsible for making decisions about those activities (Zmud 1982, Marshall 1985). The key informant instrument differs from the Aston measure in that activities and hierarchical levels are more closely tailored to respondents. Using a key informant approach would provide a decision list more relevant to plant managers and the adoption process, but it would not solve the problem of finding meaningful and equivalent hierarchical levels.

There are two Aiken & Hage measures of decentralization: one taps decentralization of decisions about organizational resources and the other taps decentralization of work control. The first measure, "decentralization of decisions," lists four standard decisions and asks, not at what level each decision is made, but how frequently respondents participate in those decisions. The scale is thus a measure of the respondents' participation in decision-making. The second instrument, which has also been called a "hierarchy of authority" scale, is a five item measure of the respondents' perceptions of the control they have over their own jobs.

Pugh et al. (1968) claim that the Aiken & Hage instruments are "too perceptual" or subjective. Closely related is Marshall's (1985) concern that scores on the participation scale are dependant on who the respondents are, or more precisely, on the respondents' hierarchical positions in their organizations. My own concern with the participation scale is that the type of decisions listed in the instrument are inappropriate to a manufacturing setting [5]

In this study, decentralization was operationalized by two instruments one to measure decentralization of decision-making (DECENT1M) and one to measure the degree of job control (DECENT2M). DECENT1M combines features of the Aston, key informant and Aiken & Hage participation measures. DECENT1M lists a number of tactical and strategic, manufacturing-related decisions and asks respondents how frequently they participate in those decisions. The list of decisions in DECENT1M comes from Schroeder (1981) though similar lists can be found in other operations management texts.

DECENT2M is a slightly modified version of the Aiken & Hage "hierarchy of authority" or "decentralization of work control" scale (Dewar et al. 1980).

The DECENT1M and DECENT2M measures are presented in Tables 4.9 and 4.10. To be consistent with DECENT1M, the scores on DECENT2M were

[5] The four decisions listed in the Aiken & Hage participation scale are: hiring new staff, promoting professional staff, adopting new policies and adopting new programs (Hage & Aiken 1967).

reversed. A high score on either of the two measures indicates a decentralized organizational structure.

Because this study surveys only one manager from each firm, the validity of the decentralization measures rests on the assumption that the managers in the sample are from approximately equivalent hierarchical levels. If respondents are from different levels, decentralization scores may convey more information about respondent position than organizational structure. For this reason, respondent position was assessed in the face-to-face interviews. The measurement and impact of respondent hierarchical level are discussed in Chapter Five in the context of the validity of the DECENT measures.

Table 4.9
DECENTIM

Listed below are a number of decisions affecting production. How often do you usually participate in each of these decisions? (Please circle one number for each decision.)

	Never	Rarely	Sometimes	Often	Always
Setting prices of products ...	1	2	3	4	5
Deciding whether or not to manufacture a new product	1	2	3	4	5
Changing product design	1	2	3	4	5
Setting production schedules .	1	2	3	4	5
Deciding whether or not to bid on a contract to supply parts to a customer	1	2	3	4	5
Choosing suppliers of raw materials	1	2	3	4	5
Setting inventory levels and policies	1	2	3	4	5
Setting manpower levels	1	2	3	4	5
Changing plant layout	1	2	3	4	5
Deciding how much to spend on new machinery and equipment	1	2	3	4	5
Deciding on what new equipment and machinery to buy	1	2	3	4	5
Choosing from whom to buy new equipment and machinery	1	2	3	4	5
Setting quality levels and procedures	1	2	3	4	5
Setting maintenance policies .	1	2	3	4	5
Deciding to build a new plant.	1	2	3	4	5

Table 4.10
DECENT2M

Here are a few general statements about how decisions are made in some companies. How true is each statement about your company? (Circle one number for each statement.)

	Definitely False	More False Than True	More True Than False	Definitely True
There can be little action taken here until a supervisor approves the decision .	1	2	3	4
People who want to make their own decisions would be quickly discouraged here	1	2	3	4
Even small matters have to be referred to someone higher up for a final answer	1	2	3	4
In this company people have to ask their bosses before they do almost anything	1	2	3	4
Every decision has to have a supervisor's approval	1	2	3	4

I.F.ADOP (ADOPtion of flexible automation)

Innovation studies typically measure adoption in one of four ways: adopt/not adopt, delay in adoption, extent of adoption and number of innovations adopted (Cohn & Turyn 1980). The most commonly used measure in studies of adoption of flexible automation is a variation of the adopt/not adopt dichotomous variable: purchased flexible automation technology/not purchased technology (Avlonitis & Parkinson 1986). Cook (1986) argues against dichotomous measures of adoption of flexible automation:

> At the extreme is a dichotomous measure that equates adoption to having the technology anywhere on site. At the other extreme is a dichotomous measure where the technology must be fully implemented for the plant to qualify as an adopter (p. 59).

Because flexible automation can be purchased and implemented in small increments, Cook (1986) advocates a finer measure of adoption of these technologies. In his study of robot adoption he asks respondents to date the start of planning and the start of operations of first, second, and third robotics projects.

The self-administered questionnaire incorporated two measures of adoption. ADOP1M, as shown in Table 4.11, conceptualizes adoption as the purchase of a flexible automation technology but distinguishes between a pilot project and "substantial use" of the technology. This measure thus addresses some of Cook's concerns.

Table 4.11
ADOP1M

Flexible automation refers to any of the manufacturing technologies listed below. Does your plant have any of these technologies? (Please circle one number for each technology.)

	Would Have No Use In Your Plant	Applicable But Not Used In Your Plant	In Trial Or Limited Use In Your Plant	Substantial Use In Your Plant
Industrial Robots	1	2	3	4
Programmable Controllers	1	2	3	4
Numerically controlled machines (NC)	1	2	3	4
Computer controlled NC machines (CNC)	1	2	3	4
Computerized material handling equipment ...	1	2	3	4
Computer-aided inspection and testing devices	1	2	3	4
Computer-aided design (CAD)	1	2	3	4
Integration between CAD and computer-aided manufacturing (CAD/CAM)	1	2	3	4

The mail questionnaire also included a four item measure, ADOP2M, which asks respondents to compare their plants' adoption of flexible automation with that of competitors. ADOP2M is the mean of each plant manager's score on the same four automation items that were used in the survey of GMC personnel and shown in Table 3.2.[6]

I.G. Other Variables

A number of other items were included in the mail questionnaire. These items are presented in Table 4.12, and discussed in the context in which they are applied in Chapters Five and Six.

Table 4.12
Other Items in the Mail Questionnaire

At the present time, how many people are employed full-time at your plant? ________ people

About what percent of your plant's total sales last year were made to General Motors? ____%

How many years have you been with your company? _____ years

How many years have you been in your current position? ____ years

---

[6] There is one difference between ADOP2G and ADOP2M. As shown in Table 3.2, the anchors of the ADOP2G scale are "Worst" and "Best." These terms may be appropriate for external raters, but to avoid communicating a pro-technology bias to plant managers, the ADOP2M anchors were "Lowest" and "Highest."

Section II: Face-to-Face Interviews and Plant Visits

II.A. Collecting and Coding the Interview Data

The protocol used in the personal interviews is presented in Appendix D. All but two of the 29 interviews were tape-recorded. One of the interviews was not recorded because of high noise levels in the manager's office and another was not recorded because the manager appeared to be very tense about being interviewed. After all the interviews were completed, I reviewed and coded the information from the plant visits using the coding sheet shown in Appendix E. The reliability of the coding process was enhanced by two factors. First, the coding process incorporated three sources of information: notes taken during the interviews, tape-recordings of the interviews, and information gleaned from the plant tours. Interview notes were checked against interview recordings, and, where possible, notes and recordings were checked against observations from the plant tours. Second, the coding process was conducted in a consistent and methodical fashion during a one week period after all data had been collected.

II.B. Face-to-face Interview Variables

A number of interview and plant visit variables figure in the deliberations of Chapters Five and Six, but, in this chapter, I will only describe those variables which appear in Table 4.1 and which are used in main tests of the Model A and B hypotheses.

EMFEVL1F is the interview version of the Hopwood measure of "supervisor evaluation style." Plant managers were given cards, on which were printed the 11 criteria of EMFEVL1M, and asked to rank the criteria in terms of importance in their evaluations. Managers often had to be pushed to priorize the criteria. In some cases, managers had to be asked directly if accounting measures were used to evaluate performance, and if so, which criterion, "meeting the budget" or "lowering costs," was most important.

TMHOR3F is the interview version of TMHOR3M, which asked managers to report on the payback period used to assess potential investments in flexible automation, and EMFJST2F is a measure of the importance of payback in justifying proposals to purchase new equipment. Respondent replies to the question, "How important is payback in getting approval to buy new equipment?" were coded 0 (not important), 1 (somewhat important) and 2 (very important).

ADOP3F is a count of each plant's flexible automation technologies. A plant with 3 robots, 1 CNC machine and 2 computerized testing machines would score 6 on ADOP3F. Because, all things being equal, larger plants could be expected to have higher scores on ADOP3F, another variable was created by adjusting ADOP3F for plant size. ADOP4FM is a ratio calculated by dividing a plant's ADOP3F score by the number of plant workers as reported in the mail questionnaire.. A plant with an ADOP3F score of 6 and 100 workers would register .06 on ADOP4FM.

One final measure of adoption, ADOP5F, is a single, 5 point item anchored by "Low Flexible Automation Adoption" and "High Flexible Automation Adoption." ADOP5F represents my rating of the flexible automation levels of the 24 production facilities that I personally inspected.

Section III: Chapter Summary

This chapter described the mail questionnaire and face-to-face interview instruments that were used to measure the variables that test Models A and B. The operationalization of the constructs in Models A and B was guided by two principles: where possible, I used established instruments, and where possible, I employed multiple measures and multiple methods of measurement. Because it is a critical variable in studies of this type, I paid special attention to developing measures of adoption of flexible automation. Having presented the history and form of the mail and interview variables, I will now analyze the results of the study.

CHAPTER FIVE

This chapter presents the results of the statistical tests of the hypotheses. The chapter is organized into six sections. Section I explains the decision to use non-parametric statistical tests. Section II examines some descriptive statistics of the participating plants and managers that demonstrate the sample is appropriate and unbiased. Section III discusses measurement issues and Sections IV and V present the actual tests of the Model A and B hypotheses. Section VI summarizes the chapter.

Section I: Statistical Methods

Most of the measurements used in this study meet the minimum requirement for parametric tests of significance (Kerlinger 1973). However, some of the measures are only ordinal and, with missing data, the number of cases in some analyses dips below 30. Therefore, to be consistent and conservative, I tested the hypotheses with non-parametric statistics. I would note that tests of all major hypotheses with parametric alternatives lead to exactly the same conclusions.

Unless otherwise stated, all statistical tests use the Spearman rank correlation coefficient. This non-parametric statistic is about 91% as efficient as the Pearson correlation. That is, if a correlation between two variables does exist in a population, the Spearman statistic will have the same level of significance in a sample of 30 as the Pearson statistic has in a sample of 27 (Siegel 1956).[1]

When presenting correlation coefficients, I will also report the number of cases in each analysis (n) and the significance levels (p). Numbers of cases differ from analysis to analysis because cases with missing values are eliminated on a pairwise basis. That is, cases are omitted only in those analyses in which data is missing. Where nonresponse was a potential problem, I checked for patterns of nonresponse and found no evidence of nonrandomness. Key correlations were recalculated using listwise deletion and these correlations were consistent with the casewise deletion results.

In keeping with the argument that this thesis explores a much discussed but little studied area, I use two-tailed statistical tests. Even in tests of the main hypotheses, where the literature clearly predicts the expected sign of relationships, I maintained a conservative two-tailed approach.

Since some statistical power has already been sacrificed by using non-parametric techniques, I opted for a significance criterion of p=.10. A two-tailed test with a rejection level of p=.10 is as powerful as a one-tailed test at p=.05 (Cohen 1977). With two-tailed tests, p=.10,

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[1] Data analyses were performed with SPSS[x] (Version 2.2), on the Queen's University IBM VM/CMS mainframe.

and sample sizes of about 30, correlations would have to be greater than .30 to be judged significant. Cohen (1977) suggests that correlations of .30 indicate "medium effect size."

To sum up, given a sample size of about 30, the statistical tests used in this study are powerful enough to reject the hypotheses if any of the MACS variables have at least a "medium-sized" correlation with adoption. To put it in another way, the tests are powerful enough to reject a hypothesis if the MACS variables associated with that hypothesis explain at least 10% of the variance in the level of adoption. The literature reviewed in Chapter Two assumes that MACS play a major role in adoption. It should not be too much to expect that if MACS are an issue in adoption of flexible automation, the MACS variables should explain at least 10% of the variance in adoption.

Section II: Sampling Issues

I have already addressed one of the most important sampling issues: self-selection of participants. As shown in Chapter Three, there was no significant difference between participants and non-participants in terms of the GMC personnel survey scores on automation and success.

In this section, I will examine a number of other plant and managerial characteristics that relate to the appropriateness of the sample. I will frame these sampling issues in a series of questions, first about the plants and then about the managers.

II A. Plant Sampling Issues

To what extent are the plants in the sample suppliers to General Motors? One of the reasons for studying a sample of GMC part suppliers was to control for environmental "noise." GM was expected to be a major customer of plants in the sample. But if sample plants are too dependent on GM business, the external validity of the study would be reduced. Therefore, a "good" sample would be one with plants that depend on GM for some, but not all of their sales.[2]

Of the 32 plants in the study, all have some dealings with GM. Sales to GM range from 3% to 95% of plant sales. Only 7 plants depend on GM for less than 30% of sales and only 5 for more than 70%. The mean percent of sales to GM is 45% and the median 47%. These results indicate that while the sample plants represent GM suppliers, they also represent suppliers of other assemblers. Furthermore, the sample plants are typical of most Canadian parts suppliers in that they have more than one major customer.

Are the plants typical adopters of flexible automation? I chose to study adoption of flexible automation in this sample because, as shown in Chapter Three, there is some evidence of adoption of flexible

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[2] Some plants shipped parts to both GMC and American assembly plants. For the purposes at hand, it was sufficient to know per cent of total plant sales to all GM assembly plants.

automation in the automotive industry in general, and in these plants in particular. As a further check on patterns of adoption in the sample plants, I compared some sample and industry statistics.

Table 5.1 is similar to Table 3.1, except that a third column has been added for the results of this study.[3] Table 5.1 shows that sample adoption rates are higher than industry rates for robots, programmable controllers, computer-aided inspection and testing devices, and CAD Computerized material handling equipment adoption rates are comparable across the three studies, while CNC rates are lower in the sample. None of the plants in the study had a working CAD/CAM system, although 7 of the plants had CAM systems with potential for CAD interface.

[3] Only the 29 plants which I personally visited are discussed here. The mail questionnaire did not address adoption in such detail.

Table 5.1
Flexible Automation Adoption Rates

Technology	% of *firms* as reported by Automotive Industry Human Resources Task Force (1986)[1]	% of *firms* as reported by Ontario Centre for Advanced Manufacturing (1986)[2]	% of *plants* as reported by this study
Industrial Robots	18%	19%	59%
Programmable Controllers	49%	27%	86%
CNC Machines	18%	37%[3]	10%
Computerized Material Handling	25%	29%	24%
Computer-aided Inspection and Testing	43%	35%	76%
Computer-aided design (CAD)	11%		55%[4]
Integration between CAD and Computer-aided Manufacturing (CAD/CAM)	4%	37%	0%[5]

Notes:

1. Percentages taken from raw results supplied by the Automotive Parts Manufacturers' Association of Canada
2. Reported results are for SIC 37 which includes manufacturers of automobiles, boats and airplanes.
3. Combines figures for NC and CNC equipment.
4. Includes off-site installations accessible to plant.
5. Seven of 29 or 24% of the plants had CAM systems with potential for CAD interface.

The lower CNC adoption rates in this study can be explained by the fact that CNC technology is usually applied in the machining of metal, and few of the plants in the study machined metal.

Other differences between industry and sample rates of adoption can be explained by looking at when sample plants first purchased flexible automation technologies. The two industry surveys referred to in Table 5.1 were conducted several years ago. Forty-seven percent of the robot adopters in this study had purchased their first robots within the past year and 59% within the past two years. And 62% of the plants with programmable controllers had adopted this technology less than two years ago. Many of the computerized inspection and testing machines and CAD systems were also new. Recent purchases of advanced technologies explain why some of the adoption rates reported here are higher than rates reported in previous studies.

To answer the question at hand, it appears there are no major, unexplained differences between the patterns of adoption of flexible automation in the study's sample plants and in the industry in general.

II.B. Respondent Characteristics

Are the survey respondents plant managers? All 29 managers who were personally interviewed met the formal definition of plant manager: they were responsible for the operation of their plants and they could initiate but not approve capital budgeting proposals. Nevertheless respondents were clearly not all alike. Some were responsible for both manufacturing and sales, others only for manufacturing. Some were part owners of their firms and had a direct say in capital expenditures, others only initiated proposals. Some reported directly to top management, others were four or five levels below top management. I captured these differences in two managerial position variables: MANPOS1F (hierarchical level) and MANPOS2F (cost/profit centre). Summary statistics of MANPOS1F and MANPOS2F are displayed in Table 5.2.[4] While the respondents were, by definition, plant managers, there is sufficient variation in the two hierarchical variables to warrant controlling for MANPOS1F and MANPOS2F in the tests of the Model B hypotheses, and as will be argued shortly, also in the tests of the Model A hypotheses.

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[4] As a test of the validity of the MANPOS1F and MANPOS2F measures, I checked the correlation between the two variables and found that, as might be expected, upper-level managers are more likely to manage profit centres than lower-level managers. The correlation between MANPOS1F and MANPOS2F is .61, n=28, p=.00.

Table 5.2
Frequencies of Hierarchical Variables

MANPOS1F	
1 - lower-level manager	5 respondents
2 - mid-level manager	9 respondents
3 - upper-level manager	15 respondents
MANPOS2F	
1 - no sales responsibility	18 respondents
2 - some responsibility for sales	2 respondents
3 - responsibility for sales	8 respondents

How long have respondents and their supervisors held their current positions? Job tenure could affect the results of this study in two ways: a respondent only recently appointed to his position might give less accurate reports of the variables of interest, and recent changes in the respondent/supervisor dyad could mean changes in how MACS are used (Hopwood 1973). My conclusions are valid only in so far as the measured characteristics and uses of MACS are those associated with the adoption of flexible automation. If there had been changes to a MACS after the adoption of flexible automation, it would be misleading to associate the new characteristics and uses with the adoption.

The mail questionnaire responses showed that on average, the 32 managers in the study had been with their firms, 9.5 years and in their current positions, 3.6 years. However, 5 of the respondents had been with their current company one year or less and 8 respondents were in their current position one year or less. There was an obvious need to check the accuracy of responses to key questions and to ensure that adoption measures were matched with the appropriate MACS variables. Verification was accomplished in the face-to-face interviews.

The interview process revealed that respondents had no problem in providing the information required for the study. The interviews also confirmed that despite changes in personnel, the characteristics and uses of MACS remained stable over time. That MACS are stable is not surprising when one considers the forces that work to keep a MACS from changing: functional fixation (Ijiri 1967), the preservation of power (Markus & Pfeffer 1983), and contagion effects (Hopwood 1973). In several cases, even changes in firm ownership had not changed the MACS.[5] And, in the few instances where long-time plant managers reported some changes to the MACS, I ascertained that the changes in the MACS had preceded the adoption of flexible automation. I would therefore conclude that job tenure of plant managers was not a factor in this study.

5 To be fair, changes in plant ownership were all very recent

Section III: Measurement Issues

III.A.Measures of MACS and Decentralization

III.A.1.Reliability

Table 5.3 summarizes the reliability checks performed on the measures of MACS and decentralization. After discussing the reliability tests, I will look at the measures' construct validity (convergent and discriminant validity).

As shown in Table 5.3, all multi-item measures have Cronbach's alphas greater than the minimum standard of .50, but three measures have alphas below .70.[6] I will discuss the low reliabilities of these three measures: TMHOR1M, TMHOR2M and EMFJST1M.

TMHOR1M and TMHOR2M are formative rather than reflective measures (Fornell 1984). That is, I do not posit an underlying latent variable that "causes" TMHOR1M and TMHOR2M. Each of these two constructs is defined as a sum of three possibly independent items. For example, TMHOR1M is the sum of scores on the following items: the period of time covered by the most frequent budget reports, the time horizon of

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[6] The lower limit of acceptability for Cronbach's alpha is .50 (Merchant 1981, Nunally 1967). However, Nunally (1978) suggests a more stringent criterion of .70 for measures used in the "early stages of research."

the most immediate budget targets, and the shortest time span of the formal evaluations. Logically, scores on these three items need not be correlated and low inter-item correlations result in low reliability coefficients. Since there is no reason for the items in TMHOR1M and TMHOR2M to be correlated among themselves, the low reliability of these two measures does not imply low validity. However the low reliability scores do indicate a need to test not only the relationship between the two variables and ADOP, but between the individual items in the two measures and ADOP

The third measure with low reliability is EMFJST1M The reliability of this scale can be raised to .63 by dropping the item "When it comes to new technology, the only thing top management wants to know is 'How much will it cost?'." However, the improvement in Cronbach's alpha is marginal and the item has face validity, so it is retained in the scale.

Table 5.3
Reliability Tests

Internal Consistency

Measure	Number of Items	Cronbach's Alpha
EMFEVL2M emphasis on budget variances	4	.76
EMFEVL3M budget motivation	10	.92
TMHOR1M lower limit time horizon	3	.55
TMHOR2M upper limit time horizon	3	.61
EMFJST1M emphasis on financial justification	4	.59
DIFQUN1M difficulty in quantifying costs/benefits	6	.71
DECENT1M decentralization of decision-making	15	.[illegible]4
DECENT2M decentralization of work control	5	.70

Alternate Form / Test-Retest Reliability

Replicated Measures	Spearman r	Sample Size	Significance
EMFEVL1M and EMFEVL1F	.39	n = 22	p = .04
TMHOR3M and TMHOR3F	.63	n = 22	p = .00

Before proceeding further, I would comment on the appropriateness of calculating Cronbach's alphas with small samples. Nunally (1967) suggests internal reliability tests should have 5 to 10 times as many cases as items per measure. Reliability estimates may be over-estimated for those measures that do not meet this requirement (Peter 1979). However, a comparison of the Cronbach's alphas in Table 5 3 with those reported by other researchers shows that over-estimation of reliability is not a problem in this study. Merchant (1981) reports a reliability of .84 for EMFEVL2M and reliabilities of .79 and 74 for the two subscales of EMFEVL3M Dewar et al (1980) report Cronbach's alphas ranging from .70 to .96 in several applications of DECENT2M. However, the reliability estimate of .96 comes from a sample size of only 16 and may overestimate true reliability The reliability estimate of .70, from a sample of 72, is more accurate and is consistent with the alpha of DECENT2M in this study.

Moving on to the alternate form/test-retest reliabilities, the low correlation between replications of EMFEVL1 casts doubt on the reliability (and hence validity) of these instruments The low correlation of .39 between EMFEVL1M and EMFEVL1F, can be partially explained by the time span between replications, which in most cases was about 2 months. And of course the two measures were administered by different methods: EMFEVL1M by mail questionnaire and EMFEVL1F by personal interview. As well, the results of the mail questionnaire were highly sensitive to the coding scheme. For example, two of the managers ranked "cost" as the fourth most important criterion in how they were evaluated. They were classified in the Profit Oriented category of EMFEVL1M. However, the personal interviews clearly showed them as belonging to the Nonaccounting category. A different coding scheme for EMFEVL1M, which considered only the top three criteria, would have correctly identified the role of MACS in the evaluation of these two managers.[7]

Although low correlations between EMFEVL1M and EMFEVL1F may mean that either or both of the instruments are invalid, there is evidence of two fundamental problems with the mail version. First, 6 of the 32 or 19% of the respondents did not properly complete EMFEVL1M.[8] They assigned numbers from 1 to 4 to all 10 criteria. That is, they listed several criteria as being most important in their evaluation, several criteria as being second most important, and so on. These multiple responses could not be coded. A few of the improper responses may have been caused by a misunderstanding of the instructions, but in the face-to-face interviews it was found that many managers are evaluated on multiple, equally important, criteria and judging from their reactions, these managers could not easily priorize evaluation criteria.

A second fundamental problem with EMFEVL1M is that its validity depends on the assumption that respondents interpret words like "cost" and

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[7] As indicated in Chapter Four, I used Hopwood's coding scheme but, as suggested by Brownell & Hirst (1986), considered the four highest ranking criteria.

[8] In Brownell (1982), 8 of 48 or 17% of the respondents improperly completed the Hopwood evaluative style measure (EMFEVL1M).

"budget" the same way. EMFEVL1M was originally designed to survey manufacturing managers <u>within</u> a single large company and so Hopwood (1973) and Otley (1978) tailored the instrument for the company in which it was applied. For example, Otley translated Hopwood's "concern for cost" to "concern for efficiency." Other researchers have used EMFEVL1M in mail questionnaire studies of managers of manufacturing and non-manufacturing departments of the same firm and managers of business units in several different firms (Brownell and Hirst 1986, Govindarajan 1987). Results of this study would suggest that it may be inappropriate to use the mail questionnaire version of EMFEVL1 to survey managers in different firms. From the interview sessions it became obvious that managers had different interpretations of evaluation criteria. For example, some managers interpreted "budgets" to mean cost objectives while others defined budgets as detailed plans for achieving targets for sales, costs, return on investment, worker safety, and customer satisfaction. Differences in interpretation of EMFEVL1 criteria could only be reconciled through personal interviews. I therefore decided to use EMFEVL1F as the definitive measure of evaluative style and dropped EMFEVL1M from the study.

Referring to Table 5.3 again, and the last of the reliability tests, there is a high correlation (.63, p=.00) between TMHOR3M and TMHOR3F, the mail questionnaire and personal interview measures of payback. In the interviews, managers often differentiated between formal firm payback criteria and personal, rule of thumb, payback. For example, one manager who had reported a 24-month payback criterion on TMHOR3M admitted to using a 12-month payback to evaluate projects because he wanted to make sure he had "winners." When interviewed, managers differentiated between personal and firm payback criteria, I coded TMHOR3F with the personal criteria. Thus, TMHOR3M could be interpreted as the formal, firm payback criteria and TMHOR3F as the informal, personal payback criteria. Since TMHOR3M and TMHOR3F are highly correlated, and since there is not much difference in the means of the two measures I retained only one of the measures.[9] I chose TMHOR3F because it represents the actual payback criterion used by the plant manager. The TMHOR3M response was used in cases where TMHOR3F was missing.

To recap this discussion of reliability, all multiple-item measures met minimum standards for internal reliability. However, analysis of the low alternate form reliability of EMFEVL1 indicated problems with the instrument and led to the abandonment of the mail questionnaire version, EMFEVL1M.

III.A.2.Construct Validity

Kidder (1981) says that construct validity requires agreement on scores obtained with instruments measuring the same construct (convergent validity) and some differences on scores obtained with instruments measuring different constructs (discriminant validity). Though there

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[9] The mean TMHOR3M payback is 28 months and the mean TMHOR3F payback, 27.4 months.

are no set criteria for establishing construct validity, correlations among measures of the same construct should be larger than correlations among measures of different constructs. A look at Table 5.4 shows that the pattern of correlations among the MACS and decentralization variables generally supports construct validity but that there are only small differences between convergent and discriminant correlations. For example, while the correlations among the EMFEVL and EMFJST variables are generally higher than the correlations between EMFEVL and EMFJST variables, the average correlation among measures of EMFEVL is only .38 and the average correlation between EMFEVL and EMFJST measures is .23.

One of the conclusions that may be drawn from Table 5.4 is that each of the measures used in this study represents related but separate constructs. Thus, even though I use the shorthand EMFEVL for "emphasis on MACS in evaluating managers", I am actually referring to three constructs: performance evaluation style (EMFEVL1F), emphasis on budget variances (EMFEVL2M), and intrinsic and extrinsic motivation of budgets (EMFEVL3M). In other words, I am defining "emphasis on MACS in evaluating managers" in terms of EMFEVL1F, EMFEVL2M and EMFEVL3M. Similar interpretations may be made of the TMHOR, EMFJST and DECENT variables.[10]

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[10] This is common practice. For example, Merchant (1981) labels the three multi-item variables, "required explanations of variances," "reactions to expected budget overruns" and "link with corporate reward system," as measures of "importance of meeting budgets."

I would make two other observations of Table 5.4. First, TMHOR1M and TMHOR2M are uncorrelated. A MACS that is rated high on TMHOR1M may be rated high or low on TMHOR2M. Managers can make separate decisions on the length of the short-term MACS time horizon and the length of the long-term MACS time horizon. Second, there may be a methods bias or methods factor operating on EMFJST1M. EMFJST1M tends to correlate more highly with mail questionnaire measures than with face-to-face measures

In concluding this discussion of construct validity, there is nothing in the pattern of relationships among the MACS and decentralization variables to indicate that the measures are not valid. However, an analysis of the correlations among the variables from the perspective of convergent and discriminant validity does suggest that the variables should be interpreted as measures of separate constructs.

[redacted]

Table 5 4

Convergent and Discriminant Validity

	EMFEVL1F	EMFEVL2M	EMFEVL3M	THEOR1M	THEOR2M	THEOR3F	EMFJST1M	EMFJST2F	DIFQUN1M	DECENT1M
EMFEVL2M	37 n 28 p 05									
EMFEVL3M	31 n 28 p 11	47 n 30 p 01								
THEOR1M	22 n 22 p 33	- 50 n 24 p 01	- 16 n 25 p 45							
THEOR2M	- 56 n 22 p 01	- 03 n 24 p 88	- 08 n 25 p 71	00 n 25 p 99						
THEOR3F	- 07 n 25 p 73	- 12 n 27 p 54	14 n 27 p 49	15 n 23 p 50	36 n 23 p 09					
EMFJST1M	- 11 n 28 p 57	33 n 31 p 07	31 n 30 p 10	- 35 n 24 p 10	43 n 24 p 04	11 n 27 p 59				
EMFJST2F	36 n 27 p .06	29 n 26 p 15	00 n 26 p 99	- 38 n 21 p 09	- 07 n 21 p 77	11 n 24 p 60	45 n 26 p 02			
DIFQUN1M	- 04 n 28 p 86	07 n 31 p 71	14 n 30 p 47	- 06 n 24 p 78	- 20 n 24 p 34	- 23 n 27 p 25	11 n 31 p 54	- 21 n 26 p .31		
DECENT1M	- 14 n 28 p 49	- 10 n 31 p .60	- 06 n 30 p 74	30 n 24 p 15	32 n 24 p 13	11 n 27 p 59	26 n 31 p 16	14 n 26 p 48	04 n 31 p 83	
DECENT2M	- 23 n 29 p 22	02 n 31 p 91	02 n 31 p 94	11 n 25 p 59	22 n 25 p 29	21 n 28 p 28	12 n 31 p 53	- 08 n 27 p 70	- 20 n 31 p 29	10 n 31 p 62

[redacted]

III.B. Measures of Adoption

Six instruments were used to measure adoption: an eight item scale from the mail questionnaire (ADOP1M), a four item assessment by each manager of his plant's level of automation (ADOP2M), a four item assessment by GMC personnel of each plant's level of automation (ADOP2G), a count of flexible automation installations from the face-to-face interviews (ADOP3F), a ratio created by dividing ADOP3F by the number of plant workers (ADOP4FM), and my rating of the adoption levels of the 24 plants I toured (ADOP5F).

ADOP2M and ADOP2G have Cronbach's alphas of .89 and .93. The other multiple item instruments are simply equipment counts and require no tests of internal reliability.

Table 5.5 shows that five of the six measures are significantly correlated among themselves.[11] The one exception is ADOP2G. There are two reasons why ADOP2G, the GMC rating of adoption, is not significantly correlated with the other variables. First, the GMC survey was conducted several months before the survey of plant managers. As noted earlier, many of the flexible automation technologies counted in this study had been implemented very recently and may not have been known to the GMC raters. As well, GMC raters may

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[11] Since the direction of the relationships among the ADOP variables can be expected to be positive, Table 5.5 shows one-tailed probabilities. A significant correlation is one with a probability lower than .05.

have only incidental knowledge about supplier technologies. Things like quality, on-time delivery, and price would be of more immediate concern to raters.

Table 5.5
Convergent Validity of Adoption Measures

(One-tailed Probabilities)

	ADOP1M	ADOP2M	ADOP2G	ADOP3F	ADOP4FM
ADOP2M	.47 n 29 p .01				
ADOP2G	.07 n 28 p .37	.19 n 31 p .15			
ADOP3F	.63 n 26 p .00	.78 n 29 p .00	.17 n 28 p .20		
ADOP4FM	.57 n 26 p .00	.56 n 29 p .00	.27 n 28 p .08	.66 n 29 p .00	
ADOP5F	.67 n 21 p .00	.67 n 24 p .00	.24 n 23 p .14	.78 n 24 p .00	.86 n 24 p 00

I considered combining the five correlated measures of adoption into one scale, which would have a Cronbach's alpha of .82, but this approach would have several shortcomings. Only 21 plants had a complete set of scores on the 5 measures. Another alternative, analyzing 5 separate adoption measures, would be too unwieldy

Therefore, through a process of elimination, I chose two of the "best" variables to represent ADOP.

ADOP5F, which is my assessment of the level of adoption of flexible automation of the plants I toured, may be the best single measure of adoption but it has too many missing values (n=24). ADOP1M has fewer missing values (n=29) but I have some reservations about the validity of the measure. In my interviews with managers I discovered they had very different interpretations of the phrases "in trial or limited use in your plant" and "substantial use in your plant." In one case, a plant with one yet-to-be unpacked robot scored the same on the robot item of ADOP1M as a plant with a dozen operating robots. As well, some managers confused "plant" with "firm." In the most extreme example, one manager reported substantial use of all eight technologies listed in ADOP1M. Upon visiting the plant I discovered that almost all of the technologies were being used by a nearby, sister plant, which operated an entirely different business. Finally, ADOP1M is a more "lumpy" or "less fine" measure of adoption than the actual machine counts of ADOP3F and ADOP4FM.

The remaining variables, ADOP2M, ADOP3F and ADOP4FM, are all satisfactory measures of adoption, but for the sake of parsimony I use only ADOP4FM and ADOP2M. I chose ADOP4FM because, as Table 5.5 shows, the two external ratings of adoption (ADOP2G and ADOP5F) correlate more highly with ADOP4FM than with ADOP2M and ADOP3F. On this basis, ADOP4FM has the highest face validity.

I chose to use ADOP2M, respondents' self-ratings, as the second measure of adoption because it provides a different method triangulation on ADOP4FM. Furthermore, while there are ADOP2M scores for all 32 plants, ADOP3F has three missing values. Finally, because ADOP2M is highly correlated with ADOP3F (.78), ADOP3F may be dropped with little loss of unique variance.

Summing up, after going through the process described above, I chose to use ADOP2M and ADOP4FM as measures of adoption. Together, these two very different measures, give a better representation of the construct, "adoption of flexible automation," than would any single measure.

III.C Summary Statistics

Table 5.6 presents summary statistics of the main variables in Models A and B. Along with the mean, possible range, actual range and standard deviation, the table also shows a theoretical mean for Likert-scale instruments with neutral midpoints. For example, each of the six items of DIFQUN1M is scored on a 5-point scale with 1=strongly disagree and 5=strongly agree. The midpoint, 3, is labeled "neutral." DIFQUN1M's theoretical mean of 18 is thus a rough guide as to whether respondents agree or disagree with the proposition that it is difficult to quantify costs and benefits of flexible automation. Since the mean score on DIFQUN1M is 16.5, it can be said that, in general, respondents disagree with statements that it is difficult to quantify the benefits and costs of flexible automation. This may explain why so few of the managers I interviewed volunteered criticisms of the role of MACS in justifying advanced technologies.[12]

Table 5.6
Summary Statistics of Variables in Models A and B

Variable	Mean	Theoretical Mean	Actual Range	Possible Range	Standard Deviation	Valid Cases
EMFEVL1F	2 20		1 - 4	1 - 4	978	29
EMFEVL2M	14 45		7 - 20	4 - 20	3 394	31
EMFEVL3M	36 03	30 0	19 - 47	10 - 50	5.730	31
THBOR1M	8 16		5 - 12	3 - 20	2 357	25
THBOR2M	15 36		11 - 20	3 - 20	2 361	25
THBOR3F	28 07		6 - 60	0 - -	13 372	28
EMFJST1M	13 55	12 0	7 - 19	4 - 20	2 755	31
EMFJST2F	1 26		0 - 2	0 - 2	594	27
DIFQUN1M	16 48	18 0	10 - 24	6 - 30	3,855	31
DECENT1M	56.26		37 - 75	15 - 75	8 789	31
DECENT2M	15 84	12 5	12 - 20	5 - 20	2 172	32
ADOP2M	3 26	3 0	2 - 4 75	1 - 5	836	32
ADOP4FM	.081		0 - .33	0 - -	.082	29

Here are interpretations of other comparisons between actual and theoretical means:

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12 Fully 77% of the mail questionnaire respondents had mean scores of 18 (neutral) or lower (disagree) on items suggesting it is difficult to quantify costs and benefits of flexible automation.

EMFEVL3M On average, respondents agreed that budget performance was intrinsically and extrinsically motivating.

EMFJSTIM On average, respondents agreed that financial justification was important for approval of investments in flexible automation.

DECENT2M On average, respondents agreed that there was decentralization of work control.[13]

ADOP2M on average, respondents rated their plants as having more flexible automation than competitors

Section IV: Tests of Model A

IV.A Main Hypotheses

Table 5.7 shows the correlations between the adoption variables and each of the MACS variables. The correlation coefficients do not refute the null versions of H1, H3 and H4. The MACS variables representing those three hypotheses are not related to adoption Therefore, I must accept the following hypotheses:

- H1: Emphasis on accounting measures in evaluating managers is not related to the adoption of flexible automation.

- H3: Emphasis on financial criteria in justifying investment in flexible automation is not related to the adoption of such technologies.

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[13] There was no labelled midpoint in the DECENT2M items Respondents were forced to agree or disagree with each statement However, there is an implied midpoint of 12.5. Since DECENT2M responses were reverse coded, a score greater than 12 5 would indicate a respondent felt he had control of his own job.

H4: Difficulty in quantifying the costs and benefits of flexible automation is not related to the adoption of such technologies.

The correlations between TMHOR and ADOP partially refute H2. While the MACS short-term time horizon (TMHOR1M) and the length of payback criteria (TMHOR3F) are not significantly correlated with adoption, these two variables do have consistent, positive relationships with adoption. However, TMHOR2M is significantly correlated with both measures of adoption. This suggests that firms with longer time horizons for budget reports, performance evaluations and budget targets do have more flexible automation. To restate H2:

> The time horizon of accounting measures <u>may be</u> related to the adoption of flexible automation.

Table 5.7
Tests of Model A Hypotheses

		ADOP2M	ADOP4FM
H1	EMFEVL1F	-.28 n 29 p .14	-.08 n 29 p .66
	EMFEVL2M	.06 n 31 p .74	.02 n 28 p .93
	EMFEVL3M	.03 n 31 p .87	-.16 n 28 p .42
H2	TMHOR1M	.16 n 25 p .45	.33 n 22 p .14
	TMHOR2M *	.59 n 25 p .00	.73 n 22 p .00
	TMHOR3F	.18 n 28 p .36	.12 n 25 p .56
H3	EMFJST1M	-.07 n 31 p .71	.13 n 28 p .52
	EMFJST2F	-.31 n 27 p .11	-.04 n 27 p .85
H4	DIFQUN1M	-.19 n 31 p .30	-.09 n 28 p .63

* Only variable significantly correlated with ADOP.

To better understand the H2 results, I will look at the correlations between adoption and the six individual items in TMHOR1M and TMHOR2M. Table 5.8 lists the one-tailed probabilities of the time horizon variables with ADOP2M and ADOP4FM.[14] This table makes three points. First it shows that:

> The longer the longest time period for which budget targets are set, the greater the adoption of flexible automation.
>
> The longer the longest time span of budget reports, the greater the adoption of flexible automation.
>
> The longer the longest period of time for which formal evaluations are conducted, the greater the adoption of flexible automation.

Second, Table 5.8 shows that the correlation between the LONGEST FORMAL EVALUATIONS variable and ADOP2M is not significant at the .05 level, though the correlation between LONGEST FORMAL EVALUATIONS and ADOP4FM is significant. Both of the LONGEST FORMAL EVALUATIONS correlations must be interpreted with caution because of reduced sample size; 6 of the 32 respondents reported no formal evaluations.[15]

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[14] Having established the direction of the relationships, one-tailed tests are appropriate. To maintain the same power as for the two-tailed tests, the significance criterion has been set at p=.05.

[15] I checked if there were differences in adoption levels between those plants whose managers are formally evaluated and those plants whose managers are not. Non-parametric Mann-Whitney U Tests show no differences between the two groups on ADOP2M and ADOP4FM (p=.44 and p=.42).

Table 5.8
Correlations Between Time Horizon Items and Adoption

(One-tailed Probabilities)

		ADOP2M	ADOP4FM
TMHOR1M	TIME PERIOD OF SHORTEST BUDGET TARGETS	.08 n 30 p 34	.22 n 27 p .13
	TIME PERIOD OF SHORTEST BUDGET REPORTS	00 n 30 p .50	22 n 27 p 14
	TIME PERIOD OF SHORTEST FORMAL EVALUATIONS	29 n 26 p .07	28 n 23 p 10
TMHOR2M	TIME PERIOD OF LONGEST BUDGET TARGETS	45* n 30 p 01	45* n 27 p 01
	TIME PERIOD OF LONGEST BUDGET REPORTS	.53* n 30 p 00	60* n 27 p 00
	TIME PERIOD OF LONGEST FORMAL EVALUATIONS	.30 n 26 p .07	58* n 23 p 00

*Significant correlations with ADOP.

The third point illustrated by Table 5.8 is that the time periods of the shortest targets, reports and evaluations are not correlated with the adoption variables. Automation is related to maximum time periods rather than minimum time periods of budget targets and reports. For an idea of the effect size of long term time horizons on adoption, consider that the variable, LONGEST BUDGET REPORTS, by itself, explains 25% of the variance of ADOP2M and 31% of the variance of ADOP4FM

IV.B. Respondent Rank and Model A

Earlier, I presented evidence that respondents were at different hierarchical levels. It is possible that the MACS variables reflect not only the characteristics and uses of MACS but also respondent position. To assess that possibility, the Model A relationships were retested with statistical controls for MANPOS1F and MANPOS2F.

Table 5.9 compares the Model A zero-order Kendall rank correlation coefficients with first-order Kendall partial rank correlation coefficients. There are no large differences between zero and first order correlations, so it appears that MANPOS1F and MANPOS2F do not affect the observed correlations between MACS and adoption.[16]

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[16] SPSS^{x} was used to calculate zero-order Kendall correlations from which were calculated Kendall partial rank correlation coefficients (Siegel 1956, p. 226). Since the sampling distribution of the Kendall partial correlation is not known, tests of significance are not possible. However, Siegel (1956) gives an example where, on the basis of a small difference between zero and first-order correlations, he concludes that the relationship between two variables is relatively independent of the influence of the control variable. The discussion of partial correlations continues in Section V: Tests of Model B.

Table 5.9
Model A (Controlling for MANPOS)

	0-order Kendall r with ADOP2M	First-order Kendall r with ADOP2M (MANPOS1 Partialed Out)	First-order Kendall r with ADOP2M (MANPOS2 Partialed Out)
EMFEVL1F	-0.25	-0.26	-0.20
EMFEVL2M	0.05	0.05	0.05
EMFEVL3M	0.03	0.03	0.04
TMHOR1M	0.13	0.13	0.18
TMHOR2M	0.47	0.47	0.46
TMHOR3F	0.15	0.15	0.1[illegible]
EMFJST1M	-0.04	-0.04	-0.03
EMFJST2F	-0.27	-0.27	-0.25
DIFQUN1M	-0.13	-0.13	-0.15

	0-order Kendall r with ADOP4FM	First-order Kendall r with ADOP4FM (MANPOS1 Partialed Out)	First-order Kendall r with ADOP4FM (MANPOS2 Partialed Out)
EMFEVL1F	-0.05	-0.06	-0.07
EMFEVL2M	0.01	-0.00	0.01
EMFEVL3M	-0.11	-0.12	-0.12
TMHOR1M	0.25	0.26	0.25
TMHOR2M	0.57	0.57	0.57
TMHOR3F	0.09	0.09	0.08
EMFJST1M	0.10	0.10	0.10
EMFJST2F	-0.03	-0.03	-0.03
DIFQUN1M	-0.08	-0.08	-0.08

IV.C.Other Tests

For the final test of this section, I used non-parametric Mann-Whitney U tests to see if there were any differences in the MACS variables in plants with, and plants without, integrated installations of flexible automation. As I mentioned in conjunction with the discussion of Table 5.1, seven of the plants in the study had installed integrated automated manufacturing systems that had the potential of interfacing with CAD systems. Rather than replacing one function with a robot or a programmable controller, these firms had automated entire lines or complete manufacturing processes. I classified these firms with a dichotomous variable (CAMUSE).[17] Compared to other plants, plants with integrated systems have made a greater commitment to flexible automation.[18]

Using two-tailed Mann-Whitney U Tests, and setting the level of significance at p=.10, I found the two CAMUSE groups differed on only one variable: TMHOR2M. Plants with integrated flexible automation

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17 See Appendix E: Interview Coding Sheet.

18 As a rough guide, the least expensive integrated system in this sample cost about 10 times as much as a stand-alone robot. Integrated systems are complex and require much more management involvement than stand-alone implementations. In short, investing in an integrated systems is more of a strategic decision than a tactical one.

have longer time horizons for formal evaluations, budget reports and budget targets (p=.07).[19]

To recap this section, the tests of the Model A hypotheses clearly indicate that TMHOR2M, and in particular the length of budget targets and reports, is related to the adoption of flexible automation. None of the other variables were significantly correlated with adoption, leaving me to conclude that emphasis on accounting measures for performance evaluation, emphasis on financial measures in justification, and difficulties in quantifying automation benefits are not related to the adoption of flexible automation.

Section V: Tests of Model B

V.A Main Hypotheses

Studies have shown decentralization to be related to characteristics and uses of MACS and to adoption of innovations. As reported in Chapter 2, decentralized firms make greater use of MACS for control and decision-making and decentralization may be a positive or negative influence on adoption. Therefore, to determine the "true" relationship

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19 The strong relationship between TMHOR2M and ADOP in the 7 plants with integrated flexible automation may mask the true relationship between TMHOR2M and ADOP in the other firms. When only plants without integrated technology were considered, the correlation between TMHOR2M and ADOP2M dropped to .39 (p=.12) and the correlation between TMHOR2M and ADOP4FM dropped to .69 (p=.00). This demonstrates the consistency of the relationship between adoption and TMHOR2M in both CAMUSE groups.

between ADOP and EMFEVL and ADOP and EMFJST, the effects of decentralization must be partialed out. Here again are the two hypotheses represented by Model B:

H5: There is no relationship between emphasis on accounting measures in evaluating managers and adoption of flexible automation after the effects of decentralization are partialed out.

H6: There is no relationship between emphasis on financial criteria in justifying investment in advanced technologies and adoption of flexible automation, after the effects of decentralization are partialed out.

Partialing out the variance due to a variable may be thought of as holding that variable constant. Hypotheses 5 and 6 may thus be seen as tests of the relationship between MACS and adoption while holding decentralization constant.

Comparisons between zero and first-order correlations in Table 5.10 show that decentralization has little impact on the relationship between MACS and adoption. For example, the zero-order correlation between EMFEVL1F and ADOP2M is -.25. With DECENT1M partialed out, the correlation remains unchanged at -.25. With DECENT2M partialed out, the correlation drops to -.22. In similar fashion, Table 5.10 compares the zero-order correlation between EMFEV1F and ADOP4FM (-.05) and the correlations between those two variables when DECENT1M and DECENT2M are controlled (-.07 and -.05). Because there is little difference between zero and first-order correlations among the variables represented by H5 and H6, I must <u>accept</u> the two hypotheses.

Table 5.10
Tests of Model B Hypotheses

		0-order Kendall r with ADOP2M	First-order Kendall r with ADOP2M (DECENT1M Partialed Out)	First-order Kendall r with ADOP2M (DECENT2M Partialed Out)
H5	EMFEVL1F	-0.25	-0.25	-0.22
	EMFEVL2M	0 05	0.05	0 04
	EMFEVL3M	0 03	0 03	0 03
H6	EMFJST1M	-0 04	-0 05	-0.05
	EMFJST2F	-0 27	-0 27	-0 28

		0-order Kendall r with ADOP4FM	First-order Kendall r with ADOP4FM (DECENT1M Partialed Out)	First-order Kendall r with ADOP4FM (DECENT2M Partialed Out)
H5	EMFEVL1F	-0 05	-0 07	-0 05
	EMFEVL2M	0.01	0.02	0 01
	EMFEVL3M	-0.11	-0 11	-0 11
H6	EMFJST1M	0 10	0 07	0 10
	EMFJST2F	-0.03	-0 05	-0 03

As stated earlier in this chapter, the non-parametric Kendall partial rank correlation coefficient has an unknown distribution and therefore statements such as "there is little difference between zero and first-order correlations" are subjective To put some perspective on differences between the zero and first-order correlations in Tables 5 9 and 5.10, I present the simulation in Table 5 11 Table 5 11 shows how zero and first order Kendall correlations between MACS and ADOP may differ under various assumptions of the relationships between MACS and DECENT and ADOP and DECENT. I will explain Table 5.11 by discussing each of the columns in the table:

Column 1 Tests of Model A have already established that, with the exception of TMHOR2M, there are no significant correlations between the MACS variables and ADOP. Therefore, as suggested by the literature, I assume a negative correlation between MACS and ADOP and arbitrarily choose a value of -.20 to represent the MACS-ADOP relationship.

Column 2 Cohen (1977) defines small, medium and large correlations as .10, .30 and .50 but he notes that "one rarely if ever encounters [correlations of .10] on samples large enough to yield standard errors small enough to distinguish them from [correlations] of zero." For the purposes of the simulation, I define a small correlation to be .20, a medium correlation to be .30 and a large correlation to be .50. As suggested by the literature, MACS and DECENT are assumed to have a positive relationship and in Column 2, the relationship is allowed to vary between .20 and .50.

Column 3 Because the literature suggests that DECENT may have a positive or negative relationship with ADOP, for the sake of completeness, correlations between the two variables are allowed to vary from -.50 to +.50.

Column 4 This column presents the partial correlations between MACS and ADOP under the various assumptions of Columns 1, 2, and 3.

Column 5 This column shows the differences between zero and first-order correlations. Differences are calculated by subtracting Column 4 correlations from Column 1 correlations.

Column 5 in Table 5.11 shows that partial correlations can be very different from corresponding zero-order correlations. For example, if the correlation between MACS and DECENT was +.50 and the correlation between DECENT and ADOP was +.50, holding DECENT constant would increase the observed correlation between MACS and ADOP from -.20

to -.60. In this case, decentralization could be said to have a large impact on the observed relationship between MACS and adoption

In the simulation of Table 5.11, differences between zero and first-order correlations range from .00 to .40. Looking at the actual results, the largest difference between zero and first-order correlations is .05 in Table 5.9 and .03 in Table 5.10. If we are to use simulation differences as a yardstick, observed differences between zero and first-order correlations in Table 5.9 and 5.10 are very small. Thus, the simulation supports my earlier statement that controlling for MANPOS has little effect on the observed relationship between MACS and ADOP. And the simulation supports the contention that Hypotheses 5 and 6 cannot be rejected. I must conclude that the relationship between MACS and adoption is independent of decentralization.[20]

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[20] An analysis of the survey data reveals that there are no significant correlations between the MACS and decentralization variables and between the adoption and decentralization variables. In terms of the definition used in the simulation, all zero-order correlations are "small".

[redacted]

Table 5.11

Simulation of Partial Correlations

Column 1 Assumed Kendall r Between MACS and ADOP	Column 2 Assumed Kendall r Between MACS and DECENT	Column 3 Assumed Kendall r Between ADOP and DECENT	Column 4 Kendall r Between MACS and ADOP with DECENT Partialed Out	Column 5 Differences Between Zero and First-Order Correlations
-0.20	0.50	-0.50	0.07	-0.27
-0.20	0.50	-0.30	-0.06	-0.14
-0.20	0.50	-0.20	-0.12	-0.08
-0.20	0.50	0.00	-0.23	0.03
-0.20	0.50	0.20	-0.35	0.15
-0.20	0.50	0.30	-0.42	0.22
-0.20	0.50	0.50	-0.60	0.40
-0.20	0.30	-0.50	-0.06	-0.14
-0.20	0.30	-0.30	-0.12	-0.08
-0.20	0.30	-0.20	-0.15	-0.05
-0.20	0.30	0.00	-0.21	0.01
-0.20	0.30	0.20	-0.28	0.08
-0.20	0.30	0.30	-0.32	0.12
-0.20	0.30	0.50	-0.42	0.22
-0.20	0.20	-0.50	-0.12	-0.08
-0.20	0.20	-0.30	-0.15	-0.05
-0.20	0.20	-0.20	-0.17	-0.03
-0.20	0.20	0.00	-0.20	0.00
-0.20	0.20	0.20	-0.25	0.05
-0.20	0.20	0.30	-0.28	0.08
-0.20	0.20	0.50	-0.35	0.15

Note: The same range of differences is produced when the signs of the assumed correlations in Columns 1 and 2 are allowed to vary.

[redacted]

V.B. Respondent Rank and Model B

In Chapter Four, I stated that the validity of the decentralization measures depends on respondents holding roughly equivalent positions in their firms. As noted in Section II of this chapter, respondents differed on the two measures of hierarchical position, MANPOS1F and MANPOS2F To complete the analysis of Model B, I must therefore check for interactions between the DECENT and MANPOS variables Table 5 12 shows there are no significant correlations between DECENT1M and the two variables measuring respondent rank It is not surprising that the DECENT2M measure is not correlated with hierarchical level because DECENT2M is more a measure of firm culture than of respondent responsibility and authority However, it is a surprise that DECENT1M does not correlate with respondent rank One would expect a manager's participation in decision-making to be related to his or her position in the firm,

Table 5.12
Correlations Between Decentralization and Hierarchical Variables

		MANPOS1F		MANPOS2F
DECENT1M		.11		04
	n	28	n	28
	p	.58	p	84
DECENT2M		- 22		- 28
	n	29	n	28
	p	26	p	16

A closer look at DECENT1M suggests a reason why the measure is independent of MANPOS1F and MANPOS2F. A correlation table of the 15 items in DECENT1M suggests, and a factor analysis confirms, that the measure has two dimensions. Nine items load on "participation in strategic decisions" (DECENT1A), and 5 items on "participation in tactical issues" (DECENT1B).[21] This is not surprising. Recall that the items in DECENT1M were culled from lists of strategic and tactical decisions for which manufacturing managers are responsible. Table 5.13 shows that DECENT1A and DECENT1B are related to respondent position, but in different directions. Mangers who score more highly on participation in tactical issues (DECENT1B) hold lower rank. Mangers who score more highly on participation in strategic issues (DECENT1A) hold higher rank. It appears that DECENT1M is not related to respondent position because it has a built in control of respondent level.

Since both DECENT1M and DECENT2M are free from respondent rank bias,

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[21] One item, "participation in setting quality levels and procedures" is not related to either factor. Because of the importance of quality in the automotive industry, many firms have a separate quality control department.

both measures may be used with some confidence in the Model B analysis.[22]

Table 5.13
Correlations Between Subscales of DECENT and MANPOS

		MANPOS1		MANPOS2		DECENT1M		DECENT2M		DECENT1B
DECENT1A		.36		.32		.87		05		.09
	n	28	n	28	n	31	n	31	n	31
	p	06	p	.10	p	00	p	79	p	63
DECENT2B		-.40		-.44		.51		.19		
	n	28	n	28	n	31	n	31		
	p	.04	p	.02	p	.00	p	.32		

[22] As one final test of the Model B hypotheses I considered calculating correlations of the form:

$r_{12.(3.4)}$, where 1=MACS, 2=ADOP, 3=DECENT, 4=MANPOS.

That is, I considered partialing out respondent level variance from DECENT1M and then using this residualized variable as a control for the correlation between MACS and adoption. At about this point I was reminded of Ward's (1969), tongue-in-cheek second law of data analysis

> If results of a meaningful analysis do not agree with expectations, than a more meaningful analysis must be performed. (p. 473-474)

Section VI: Chapter Summary

This chapter began with a discussion of the appropriateness of the sample and of the measures of MACS, decentralization and adoption of flexible automation. Insights from the face-to-face interviews of plant managers were especially helpful in resolving validity and reliability issues. Analysis of the data followed, and I found that:

1. The greater the longest time period for budget reports and objectives, the greater is the adoption of flexible automation.
2. The length of the shortest time period for budget reports and objectives is not related to the adoption of flexible automation.
3. Use of accounting measures for evaluating managers and emphasis on financial arguments for justifying new investments are not related to the adoption of flexible automation.
4. Plant managers do not have difficulty in quantifying costs and benefits of flexible automation and, in any case, difficulty in quantification is not related to adoption of flexible automation.
5. Decentralization is not a factor in the relationship between MACS and adoption of flexible automation.

I will expand on these findings in Chapter Six.

CHAPTER SIX

This chapter is divided into four sections. Section I re-examines the six hypotheses in the light of the personal interviews and plant visits and offers some explanations of the statistical results. Section II suggests some opportunities for future research and Section III looks at the assumption that flexible automation is "good" for firms. Finally, Section IV makes some recommendations for managers and researchers, and brings the thesis to a conclusion.

Section I: Interpreting the Statistical Results

In Chapter Five, I presented the mail survey results along with the interview data that could be coded or quantified. In this section I will present some of the more subjective conclusions drawn from the personal interviews and plant visits. These conclusions should be interpreted as theories that might explain the statistical results.

I will begin by marshalling evidence that supports the results of the statistical tests of each of the Model A and B hypotheses. For all but one of the hypotheses, I will suggest reasons why the null was not rejected. The exception is H2, the time horizon hypothesis. For H2, I will suggest mechanisms by which budget targets and reports may impact on adoption.

I.A. H1: EMFEVL not related to ADOP

Almost all the respondents said they wanted more flexible automation for their plants. Many of the managers noted that the key to getting the flexible automation they wanted was to have a good "track record" "Heavy hitters" or "managers with good batting averages" were more likely to apply for, and get, advanced technologies. By itself, emphasis on MACS for performance evaluation may not be related to adoption of flexible automation But the interaction term, (EMFEVL x actual performance on MACS measures) may be related to adoption. Consider a situation where MACS measures are not used to evaluate managers. In such a situation it may be difficult for a manager to demonstrate competency. A history of good performance as recorded by the accounting system may make it easier for managers to get new machinery and equipment because they are able to demonstrate they have done well with what they have been given in the past.[1]

The relationships among adoption, use of MACS for scorekeeping, and managers' track record, may be affected by other contingencies. For example, the time span of performance measurement may be related to the development of track records. The automotive industry is cyclic in nature and the longer the time period over which evaluations are made, the better can top management assess performance of plant managers. Of

[1] See Pinches (1982) for a discussion of how top management perceptions of a project sponsor's record affects capital budgeting criteria and threshold levels.

course, this assumes top managers are sophisticated users of MACS. Based on the comments of plant managers, that would be a fair assumption.

Thus, H1 may not have been rejected because the relationships among EMFJST and ADOP variables may be confounded by a number of factors. Future research should test whether managers of plants with high levels of flexible automation are evaluated in terms of MACS objectives, over long periods of time, by superiors who factor out industry performance from managerial performance

I.B H2: TMHOR2M is related to ADOP

I have already referred to the possibility that long-term budget targets and reports may assist managers in creating track records But an explanation of the relationship between TMHOR2M and ADOP must also consider managerial motivation and planning resources.

Many managers stressed that successful adoption of flexible automation occurred only when new technologies were implemented in conjunction with new programs (ie. the manufacturing of new parts). Attempts to add flexible automation technologies to on-going programs often failed. I hypothesize that managers with longer MACS time horizons are more likely to be aware of and concerned about the economics of future production and thus more likely to consider incorporating flexible automation in new programs. For example, in making an input to his firm's bid on a new part for GMC, one plant manager, who had long-range budget targets and reports, discovered that the only way he could reconcile rising labour costs with GMC's expectations that prices decrease each year of a long-term contract, was to apply flexible automation to the manufacturing of the part. The firm made a bid on the part using costs based on flexible automation, won the long-term contract, and adopted the flexible automation Competitors for the GMC contract had shorter MACS time horizons and did not address the issue of rising costs and falling prices. Their bids were based on simple extrapolations of current prices and current technologies. The point is that managers with longer MACS time horizons may be more motivated to do "what if" analyses and so be more likely to adopt and successfully implement flexible automation. At the same time, these managers may have more resources to conduct long-range planning. Where long-term objectives, budgets and evaluations are the norm, it may be more acceptable for managers to commit time and money to the planning process. As one high-adopter put it: "You have to plan to have some time to plan." In this respondent's firm, lower level managers hold regular strategy and planning sessions on Saturday mornings. Contrast this culture with the one in many low-adopting firms where managers spend little time making long-term plans and are not expected to "waste time" worrying about the distant future.

In the interviews it was discovered that some managers who had reported high scores on TMHOR2M had in fact only nominal commitments to their long-term budgets and objectives. The managers in these firms had little confidence in their long-term plans which were merely pro-forma extensions of their current budgets and objectives. Understandably, they spent little effort producing and using their plans. The already significant correlation between TMHOR2M and ADOP might be even larger if the firms with pseudo-plans were to be withdrawn from future analyses.

I.C. H2. TMHOR3F not related to ADOP

The fact that payback criteria were not related to level of adoption may be explained by the ubiquity of short-term payback criteria. Managers cited three reasons for utilizing short payback periods to assess investment proposals. Proposals, especially proposals for larger investments are time-consuming. As one manager put it, "I'm not going to spend hundreds of hours working on a proposal I know is going to be shot down."[2] To avoid wasting time, managers only request monies for projects they know will be approved: projects with quick paybacks. A second reason managers use very short payback criteria is because they believe their superiors may be reluctant to continuously upgrade equipment:

> If you're not tough on your payback and your competition is, you'll be in trouble. If a better mousetrap comes along, you won't be able to get that better mousetrap because you've got this piece of equipment and you're waiting for your five-year payback on it. So this new mousetrap's out there and you can't

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[2] Managers' comments about supporting only those projects they know in advance will be approved confirm the view that MACS are especially important in the early (initiation) stages of capital budgeting (Bower 1970, Pinches 1982).

> get it because you've got the old model and you still have to rationalize it.

A third reason for short paybacks is risk aversion. Several managers described personal strategies of avoiding projects with marginal paybacks. They stated they would not propose or support projects that marginally exceeded the formal payback criteria. In other words, given the choice, managers preferred to "go for the sure thing" and the "big winners."

Short-term payback thresholds almost certainly impede investment in advanced technologies, but for the reasons cited above, almost all managers use very short payback criteria. Because there is so little variability in TMHOR3F, this variable has little explanatory power for the ADOP variables.

I will conclude this discussion of payback with a comment related to the recommendation, often cited in the literature reviewed in Chapter Two, that top management can promote adoption of flexible automation by increasing the time period of formal justification criteria such as payback. In Chapter Five, I made a distinction between formal payback criteria (TMHOR3M) and personal payback criteria actually used by managers (TMHOR3F). This study has shown that personal payback criteria are not related to level of adoption. That is not to say that increasing formal payback thresholds would not promote adoption. It would be interesting to study changes in personal payback criteria and in adoption of new technologies in firms whose top management has lengthened the formal payback requirements. In the same vein, increasing the MACS time horizon (TMHOR2M) might also be considered as a way of lengthening personal payback criteria. As Table 5.4 shows, TMHOR2M is the only variable significantly correlated with TMHOR3F (p=.09).

I.D. H3: EMFJST not related to ADOP

I will discuss three possible reasons for the low correlations among ADOP and EMFJST variables. First, the reason for the low correlations between EMFJST2F (importance of payback in justification) and ADOP may be similar to the one used in explaining the insignificant relationships between TMHOR3F and ADOP: most of the managers considered payback to be very important in justifying investment proposals and therefore high and low adopters could not be distinguished by scores on EMFJST2F. Second, EMFJST2F and EMFJST1M (emphasis on financial issues in justifying flexible automation), may figure only in the adoption of offensive integrated flexible automation. And third, EMFJST1M may be a poor measure. The two latter rationales will be discussed in greater detail. The explanations which follow are theories, and either, neither, or both of them may be true or partially true.

I.D.1.Different Types of Investments

In Chapter Five, I noted that installations of flexible automation may be classified as integrated or stand-alone and that most of the installations in this study were of the latter type and thus relatively simple and inexpensive. In discussions with managers, another investment dichotomy became evident: offensive and defensive investments. Here is how one manager distinguished between the two types:

> Defensive investments are those we have to make if we want to stay in the business we're in now. Offensive investments are for new business and we examine the payback on those very carefully.

An example of a defensive investment is the purchase of a robot to replace a human operator in a paint room because the room's environment does not meet government health and safety standards. An example of an offensive investment is the purchase of computerized equipment for testing a new part to convince customers that the firm is serious in its bid to manufacture the part.[3]

It may be that EMFJST1M and EMFJST2F are factors in adoption only when the investment being considered is an offensive investment and involves purchase of integrated automation technology. Investment proposals of a defensive nature, whether for integrated or stand-alone machinery, require little justification. And, justification of an offensive investment in stand-alone machinery is fairly straightforward: such an investment would represent either a replacement for current machinery or a minor extension of current business. However, an offensive investment in integrated flexible automation is a strategic decision and requires much more effort to justify. It may be, as shown in

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[3] Similar offensive-defensive dichotomies are noted by Bessant (1982) and Brealey & Myers (1986).

Figure 6.1, that EMFJST is a factor only in the consideration of offensive investments in integrated flexible automation.

Figure 6.1
Role of MACS in Justifying Investments

	Defensive Projects	Offensive Projects
Integrated Machinery	EMFJST1M is not related to ADOP	EMFJST1M is related to ADOP
Stand-alone Machinery	EMFJST1M is not related to ADOP	EMFJST1M is not related to ADOP

Figure 6.1 suggests that the relationship between financial justification and adoption is confounded by type of project. A worthwhile question for future study would be: Is financial justification related to the approval or rejection of integrated, offensive investments in flexible automation? Research that attempted to answer this question would require a sample of plants whose

management has considered offensive investments in integrated machinery and some of whom adopted the technology and some of whom did not.[4]

I.D.2. Semantic Problems with EMFJST1M

In the interviews, the two most often cited reasons for adopting flexible automation were to "improve quality" and to "increase capacity." However after some probing, it became obvious that when some managers talked about quality improvement they really meant lowering costs by reducing spoilage, waste and scrap. Typically, these managers manufactured products that require expensive unrecyclable materials.[5] Other managers meant "improved customer relations" when they talked about quality. These managers felt the adoption of flexible automation demonstrated their commitment to quality:

> The customer says, "You mean to tell me you can't find a single reason to embrace this modern technology that everybody is getting." Well, the answer is obvious. If everyone else says it's a good idea, they can't all be wrong. Surely you can get some [flexible automation] too.

There are similar interpretation problems with "capacity." Consider, for example, the manager who stated that major investments in flexible automation had been justified because they "increased capacity without

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[4] As described in Section II of Chapter Two, Woods et al. (1985) studied firms that approved and firms that rejected investments in integrated/flexible automation. However, the authors made no distinction between offensive and defensive proposals.

[5] Material costs ranged from 22% to 70% of total costs and averaged 49%. Even plants in the same group differed widely on material costs. For example, reaction-injection molders in the plastics group have high material costs because they cannot reuse material after it has been injected into a mold. Thermoplastic-injection molders, on the other hand, can recycle scrap and spoilage.

increasing the number of workers." Further discussions with this manager revealed that by increasing capacity he meant not only increasing volume but also widening product mix (ie. increasing flexibility). And since labour costs were essentially fixed, and since his plant was a cost centre, by increasing volume this manager was able to reduce the per part cost of labour.

Since quality and capacity both have financial implications, managers may have had trouble interpreting some of the items in EMFJST1M. This may explain the low reliability of EMFJST1M and the concomitant low correlations between the variable and ADOP.

I.E. H4: DIFQUN not related to ADOP

As reported in Chapter Five, the managers in this study generally disagreed with the proposition that it is difficult to quantify the costs and benefits of flexible automation. The interviewees seemed to be quite happy with their MACS and with their accountants.

That satisfaction can be partially explained by the fact that managers did not have to depend solely on their MACS for generating the numbers required to justify flexible automation. For example, one manager ordered engineering time studies of a plastic molding operation and found large variances in the cycle time of the manually operated machines. The manager was able to justify an investment in automation by showing that robots would save a few seconds on each part and pay for themselves in less than two years.

In general, the plant managers in the sample seemed to have little trouble quantifying the benefits of the projects they wanted and the costs of those they opposed. What difficulties there were appeared to be less related to shortcomings in the MACS than to managerial commitment to a particular project. This is not to say that managers were able to justify any technology. Management of one firm could not justify a project with a traditional approach, so they hired outside consultants to evaluate their proposal. But after tallying up their estimates of costs and benefits of the project, the consultants, who were also in the business of selling and installing advanced technologies, advised against the investment. For that firm, trying to duplicate the hand-eye co-ordination of human operators with computerized machinery was simply uneconomical. In terms of DIFQUN, if respondents' comments are taken at face value, current MACS supply sufficient information on costs and benefits of flexible automation.

A final comment on quantification concerns the role of accountants in the justification process. In many cases, respondents described their accountants as "proof readers." The accountants' role in capital budgeting is often limited to verifying that numbers in formal investment proposals are reasonable and consistent. Limited interaction between accountants and plant managers may explain why there was so little evidence of conflict between these two groups in regards to the investment process.

I.F. H5 & H6: DECENT does not affect H1 & H3 results

As shown in the Table 5.11 simulation, if controlling for DECENT was to affect the relationships between EMFEVL and ADOP, and EMFJST and ADOP, DECENT would have to have at least a "medium sized" correlation with those variables. This was not the case and Hypotheses 5 and 6 could not be rejected. I have no explanation for the low correlations between DECENT and the MACS variables, but I can speculate why DECENT and ADOP were not more highly correlated.

As recounted in Chapter One, decentralization may have an impact on adoption only when either top managers or lower level managers are opposed to a particular innovation. In this study, managers and their supervisors generally held positive attitudes towards flexible automation.[6] In one or two cases respondents were opposed to immediately installing flexible automation because they felt their firms lacked the necessary technological and organizational infrastructures.[7] However even these managers supported the adoption of computerized machinery on principle.

[6] In their study, Cohn & Turyn (1984) found that a "relative absence of conflict over adoption decisions" was a major factor in reducing the impact of decentralization on adoption of new technologies.

[7] Hill & Dimnik (1986) discuss the organizational and technological infrastructures needed for successful implementation of flexible automation.

Section II: Future Research

Throughout Section I, I commented on the need for more research on particular aspects of the MACS-adoption relationship. In particular, research is needed to discover:

1. If interactions between MACS and other variables are related to the adoption of flexible automation.

2. If changes in time periods of budget targets and reports, and changes in formal justification criteria, affect managers' personal time horizons and decision heuristics and, if so, if changes in personal time horizons and decision heuristics affect adoption of flexible automation.

3. If emphasis on financial justification impacts on decisions to invest in offensive, integrated flexible automation.

Future research of the relationship between MACS and adoption of flexible automation would have to address the problem of operationalizing EMFJST. Though EMFJST1M meets minimum standards of reliability and construct validity, the instrument could clearly be improved and the discussion of H3 in Section I gives some insight as to how this might be accomplished. Future research should, of course, be conducted on samples from other industries. I will resist the traditional exhortation that future research be conducted on larger samples. As long as the research methodology involves, as it should, plant visits and face-to-face interviews, it will be difficult for individual researchers to survey samples much larger than 30.

In addition to the research agenda presented above, two other hypotheses might be addressed in future studies.

Hypothesis: Sophistication in the use of MACS, and the "fineness" of MACS, are not related to the adoption of flexible automation.

It is my impression that high adopters of flexible automation have "finer" MACS and are more sophisticated users of these MACS than low adopters. I use "finer" in the same sense as Ijiri (1967). High adopters may have more numbers to work with. Their MACS may convey more information because costs are broken down into smaller categories. Paradoxically, high adopters may also interpret their "finer" MACS with greater skepticism. They may use the numbers generated by their MACS but they do not use them blindly. In this study, several of the high-adopter managers were former accountants. They had played a role in designing the MACS, and were fully aware of the potentials and pitfalls of their systems. These managers felt their knowledge of accounting had helped them acquire and manage advanced technologies. Alluding to the increasingly sophisticated techniques needed to manage increasingly sophisticated technologies, one former accountant said:

> The old-time plant managers were people who could yell the loudest and beat everyone up but now you don't need people who can shout and fight, you need people who are good financial managers.

In conjunction with the plant visits, I collected samples of each firm's accounting reports. An interesting future project would be to operationalize "fineness" and then test whether the fineness of the reports used by plant managers is correlated with adoption of flexible automation.

Hypothesis: The use of growth-oriented MACS is not related to the adoption of flexible automation.

Many of the low-tech plants in this study were being managed as "cash cows." Some of these plants had generated profits for decades with very little investment in new machinery and equipment. Wringing every last drop of profit from capital investments may have been an appropriate strategy for the automotive industry when it was in the mature phase of the product lifecycle. However, the automotive industry is now "dematuring" and players in the industry need strategies more appropriate to the growth phase of the product lifecycle (Jones 1985). Changes in strategy should be matched by changes in MACS and changes in management personnel (Govindarajan 1987).

Management of several of the firms in the study were abandoning their cash cow strategies and undertaking to invest more aggressively in new technologies. It would be interesting to see if the MACS of these firms and others like them are changing to accommodate the new strategies and circumstances, and if the new strategies and systems affect investment in advanced technologies.

Section III: Assumptions

I described some of the potential benefits of flexible automation when I presented the rationale for this research in Chapter One. The findings of this study may be of academic interest whether or not the benefits of adopting computer operated machines outweigh the costs, however costs and benefits are defined. But from a managerial point of view, if there is no advantage in automation, there is no interest.

It is not possible for a cross-sectional study to demonstrate whether or not automation is "good" for a firm. Even if "better" were defined as "more profitable" and firms with more flexible automation were found to be more profitable, that result might simply mean that profitable firms have more resources to spend on flexible automation.[8] However, if we were to assume that profit is an appropriate surrogate for a number of factors that define success, then the test of the value of flexible automation would be whether or not it enhances firm profit over some fairly long period of time. Restated in its most fundamental form, the question is whether more highly automated firms have a better chance of survival than firms with less automation.

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[8] "Good for the firm" can be defined in many ways (Lowe & Chau 1984). As I will shortly show, there is a spate of current articles suggesting flexible automation may not be all that good for firms. Critics of automation are using the same measures of "goodness" that were criticized for retarding the adoption of flexible automation. For example, a few years ago, top management of General Motors was criticized for being too enamored with short-term profits and thus slow in adopting flexible automation. Now that the company has invested heavily in advanced technologies, critics argue the strategy is a bad one because short-term profits are down.

Recent articles have questioned whether flexible automation is profitable. Arnholt (1986) claims that the automotive industry's "high-tech honeymoon is over" and Winter (1986) states that high-tech, which was "pumped up in the late '70s and early '80s as the Superman to save" the North American automotive industry "hasn't come close to meeting the extraordinarily high--and often unrealistic--expectations." An IMEDE mail questionnaire study of 128 plants in 30 different countries concludes:

> In perhaps the most controversial results of the study, there appears to be some doubt about the worth of some aspects of the drive for increased automation. Given the specific character of the results, it appears that for new technology to be effective it must be well integrated into the process flow. Heavy investments in just any technology do not seem to lead to higher productivity gains. This finding supports recent press articles which caution against too much devotion and dependence on technology as a cure-all for disappointing manufacturing performance. This is clearly a subject that requires careful study (IMEDE 1987).

Pity the poor manager who a short time ago was urged to adopt advanced technologies and is now told to be more cautious and not to "automate for automation's sake."

My plant tours convinced me of the absolute value of flexible automation. The visits showed me that even when the benefits of automation are less than expected, there are still many benefits. To expand on this point, I will briefly contrast one low adopter with one high adopter in the same product group. To preserve confidentiality, I will not name the group.

Low Adopter Plant

The first thing that strikes a visitor to the plant is the noise. The machines are loud but louder still are the radios blaring out from several work stations. The second thing one notices is that the plant is dirty. The floor is filthy with oil and waste material. The machinery looks old but it is not. It is dirty and unpainted. In one corner of the plant a group of people look through boxes of the previous night's production. Workers had not noticed a flaw in the process and so the shift's entire output is being manually inspected. There is a sense of urgency in the voices and manners of the managers and supervisors. A late shipment to one customer has closed down the customer's assembly line and a second shipment is running behind schedule. To try to prevent delivery problems, the firm is constructing a building next to the plant to store finished product. The plant manager admits that relations with workers are poor. One of the reasons is that workers are hired and laid off with fluctuations in the industry.

High Adopter Plant

The plant is noisy but not uncomfortably so. The floors are clean and though the plant is small there seems to be lots of room. The plant walls have been recently painted. The machinery is highly automated and workers spend most of their time examining output as it is produced. Everything seems to be under control. Workers and managers appear to be cool and calm. The plant is undergoing substantial renovations in order to rationalize flow of raw materials and finished product. The plant manager claims that relations with workers are good. Workers are considered to be skilled and skilled labour is expensive to find and train. When automotive sales drop, the workers are kept busy with stepped-up manufacture of non-automotive products and with machine and plant maintenance (eg. painting walls). A number of plant people are co-op students from a near-by university. They are supervised by the permanent workers. The plant manager claims these students bring in information on state-of-the-art manufacturing processes and serve as a non-threatening means of in-house training for the permanent staff.

I have chosen plants at polar extremes to illustrate my point, but to varying degree, the more highly automated plants seemed to be quieter and cleaner than the less automated plants. The high adopter plants were more likely to be undergoing renovations to improve product flow and were more likely to manufacture non-automotive products in addition to automotive parts. High adopter managers and workers seemed to be calmer and more purposive and, perhaps as a consequence of their environment, more satisfied and committed to their plants and companies.

One of the arguments against emphasis on technological innovation is that "people, not machines, are the answer" to productivity problems (Arnholt, 1986). My impression is that adoption of flexible automation has a direct impact on the efficiency of the manufacturing process and an indirect one through increased worker commitment and motivation. Furthermore, the installation of flexible automation seems to serve as a catalyst for improvements in work flow and product design.[9] Even when managers felt the initial installation of flexible automation to be a failure, they argued that the experience had given them new insights and motivation to improve the production process.

That is not to say that flexible automation is without its drawbacks. On the downside, major investments in advanced technologies have proven to be more expensive than expected. In several publicly held firms, high adopter plants were reporting low returns on assets employed and in some cases were being divested because their top management felt they could achieve better returns elsewhere. It may be argued that in these situations the MACS is undervaluing the high-tech plants. While

[9] Ayres and Miller (1983) present a model of how adoption of advanced technologies can catalyze organizational and technological change.

this may be true, and it may illustrate a shortcoming in the MACS, a more likely explanation of the divestment strategy is demands of shareholders and fears of take-over. If this is the case, then the problem, if there is one, may lie with external reporting or financial accounting and not internal MACS.

A more prosaic problem facing adopters of new technology is keeping their high-tech machinery running. I rarely found flexible automation, especially integrated automation, to be fully operational during my visits. In describing his integrated system one manager noted:

> We have five or six robots and PLCs in that cell and each machine is up 95% of the time. But all of them have to be working for the cell to work. So if you compound all the downtimes, the cell is only working 60% of the time. Which is still better than the uptime on our old machines, but less than we expected with the new equipment.

Without being too glib about the utilization problem, in most cases where uptime was an issue, the technology was new to the plant. As experience with the new machinery increases, so too should uptime.

Section IV: Recommendations and Conclusion

This study aimed to answer four questions:

1. Is the use of accounting measures to evaluate performance related to the adoption of flexible automation?

2. Are the time horizons implicit in MACS related to the adoption of flexible automation?

3. Is the use of financial criteria in evaluating capital budgeting proposals related to the adoption of flexible automation?

4. Are difficulties in quantifying flexible automation benefits related to the adoption of flexible automation?

The answer to questions 1, 3 and 4 is a qualified "no." The study shows that the characteristics and uses of MACS addressed by those questions are not related to adoption. Only question 2 may be answered by a qualified "yes." The length of time incorporated in budget targets and reports appears to be related to the adoption of flexible automation.

The outcomes of this study are somewhat unexpected considering the widely held view that accounting systems are impeding investment in advanced manufacturing technologies. However, the finding that MACS time horizons impact on adoption may be seen as supportive of the normative literature which recommends that top management employ accounting measures and procedures that reflect the long-term objectives of their firms. Though this study looked only at a small sample of managers and plants, the findings may apply to the adoption of stand-alone flexible automation technologies in the automotive parts industry as a whole, and perhaps to investment in advanced technologies in North American manufacturing firms in general. But even if one were to dispute the claims of generalizability, the results of this study challenge the allegations against management accounting. At the very least, this study should prompt further empirical research in the area of MACS and adoption of new technologies.

IV.A. Recommendations for Top Management

Throughout this thesis I have presented evidence supporting greater investment in advanced manufacturing technologies. The plant visits convinced me that top managers of North American manufacturing firms should promote investment in flexible automation within their firms.

This research indicates that not much need be changed in current MACS in order to create a more positive environment for adoption. The key is to extend the time horizon of the MACS. A first step would be to set budget targets for periods longer than one year. For example, rather than setting only monthly or yearly profit targets, top management could set profit targets for two or even three year periods. A second, related step, would be to provide managers with feedback on their performance on long-range targets. For example, the MACS might generate reports that track performance over several years: two or three year budget summaries rather than annual reports.

Top management must support the extension of the MACS time horizons in two ways. First, lower level managers must be rewarded on their performance on long-term objectives as reported in formal accounting reports. Second, lower level managers must be given resources for planning. Providing managers with time, staff, and training for long range planning should promote technological innovation.

Top management who implement these recommendations will have standards against which to judge managers' "track records." Managers with good "batting averages" will be more confident in initiating change and will be more likely to receive approval of their investment initiatives. If these recommendations were adopted, top management can spend less time evaluating investment proposals and more time evaluating sponsors of proposals. And instead of conducting post audits on an investment by investment basis, top management can examine the portfolio of investments controlled by each manager. Longer MACS time horizons may eventually lead to a more decentralized organizational structure where managers closest to the technology have greater responsibility for initiating and implementing technological change. In the end, this may result in more aggressive investment in advanced technologies.

I would point out that in recommending only "minor" changes to MACS, I am responding to those who advocate that major changes in MACS are needed to promote adoption. There may be any number of reasons why top managers wish to review and alter their MACS. My argument is that top managers should concentrate on time horizon issues if their objective is to create a more positive environment for manufacturing innovations.

IV.B.The Need for Field Research

Having already made several specific proposals for future research I would now stress the need for field research. While mail surveys have some definite uses and obvious advantages, the results of mail surveys must be checked against the findings of field research. There are insights and understandings of MACS that can only be obtained through interactive and open-ended research methodologies. In conducting the personal interviews I came across a good example of how on-site observation of management practice might inform the normative literature.

The normative literature on the implementation of advanced technologies argues that since the competitive environment is changing, and since production processes are changing, there should also be changes in MACS. It is presumed that managers are wasting resources on, and are being misinformed by, obsolete MACS. An often cited example of an obsolete accounting practice is the allocation of overhead on the basis of labour hours or dollars, even when labour costs are a small proportion of total costs (Seed 1984). Mail surveys confirm that many firms still allocate overhead to labour (Schwarzbach 1985), and that many managers still spend considerable time and effort investigating labour variances, even when labour costs are a small fraction of total costs. These results could be used to support the proposition that the allocation of overhead on a labour base is forcing managers to focus on unimportant labour costs and make less than optimal decisions (Kaplan 1984b). And yet, in this sample, the managers who analyze labour variances where labour is only 5% to 10% of total costs, do not use their MACS naively. Because of their experience with their manufacturing process and an understanding of the relationship between the process and accounting numbers, these managers make good use of their MACS. Minute labour variances alert the managers to specific production problems. The managers focus on labour costs, not because overhead is applied on a labour base, but because labour variances help them control the production process.

Some changes in MACS, for example allocating overhead to machine hours instead of labour hours, might not pose problems for experienced managers. But if MACS were to be drastically altered, until they came to understand the new systems, managers would be managing blind. And there is no guarantee that new untested systems will better represent the relationships between costs and cost drivers than the systems already in place. Responsible prescriptions for change must be based on field study. To conclude, a key message of this thesis concerns method of research. Understanding the role of MACS in the adoption of flexible automation will only be achieved by field research, or as Kaplan (1986c) says, by speaking directly with managers and collecting data from actual organizations.

IV.C.Thesis Summary

Critics have charged that obsolescent managerial accounting and control systems are retarding the adoption of flexible automation. A normative literature prescribes that top management should place less emphasis on accounting measures of performance in evaluating lower level managers, that the time horizons of accounting performance measures and capital budgeting criteria should be lengthened, that less emphasis should be placed on financial criteria in justifying investment in flexible automation, and that less easily quantified costs and benefits of flexible automation should be considered in appraising investment proposals. The validity of these prescriptions was tested in a sample of 32 GMC part suppliers. Self-administered questionnaires and face-to-face interviews of plant managers were used to assess characteristics and uses of accounting systems and levels of automation. Statistical tests showed that the only variable significantly correlated with automation is the "long-term time horizon of budget targets and reports." The results were interpreted in the light of plant manger interviews and plant tours. Rather than making major changes in their accounting systems, top management wishing to promote investment in new technologies, were advised to extend the time horizon of their MACS. The thesis then concluded with a discussion of future research opportunities and a call for more field research.

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1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2

MICRO D

APPENDIX A: LITERATURE REVIEW CODING

APPENDIX A: LITERATURE REVIEW CODING

CRITICISMS and PRESCRIPTIONS

CODING

Source: 1 - Management Literature
2 - Production/Engineering Literature
3 - Accounting Literature

Problem: 1 - Evaluation Period Too Short
2 - Can't Justify Flexible Automation
3 - Other

Solution: 1 - Place Less Emphasis on Accounting Measures in Evaluation
2 - Longer Time Horizon for MACS Objectives
3 - Less Emphasis On Financial Criteria In Justification
4 - Less Difficulty in Quantifying Automation Benefits
5 - Other

Method: 1 - Model Building / Speculative
2 - Personal Experiences / Anecdotes
3 - Case Study / Survey

AUTHOR(S)	TITLE	CODING
Alvontis & Parkinson (1986)	The Adoption of Flexible Manufacturing Systems In British and German Companies	Source: 2 Problem: 1 2 Solution: 1 2 4 Method: 3
Ayres & Miller (1983)	Robotics: Applications and Social Implications	Source: 2 Problem: 1 Solution: 2 5 Method: 3
Banks & Wheelwright (1979)	Operations vs Strategy: Trading Tomorrow for Today	Source: 1 Problem: 1 Solution: 1 2 Method: 3
Barrie (1986)	A Fresh Look at Accounting	Source: 2 Problem: 2 Solution: 3 4 Method: 1
Bernard (1986)	Structured Project Methodology Provides Support for Informed Business Decisions	Source: 2 Problem: 2 Solution: 5 Method: 1

AUTHOR(S)	TITLE	CODING
Blank (1985)	The Changing Scene of Economic Analysis for the Evaluation of Manufacturing System Design and Operation	Source: 2 Problem: 2 Solution: 3 4 5 Method: 1
Bylinsky (1986)	A Breakthrough in Automating the Assembly Line	Source: 1 Problem: 2 Solution: 3 Method: 3
Canada (1986)	Annotated Bibliography on Justification of Computer-Integrated Manufacturing Systems	Source: 2 Problem: 2 Solution: 3 4 Method: 1
Editors of MHE (1985)	Integrated Manufacturing: America's Competitive Strategy	Source: 2 Problem: 1 2 Solution: 2 3 4 Method: 2
Frazelle (1985)	Syggested Technieques Enable Multi-Criteria Evaluation of Material Handling Alternatives	Source: 2 Problem: 3 Solution: 3 Method: 1
French (1984)	Management Looking at CIMS Must Effectively with These 'Issues and Realities'	Source: 2 Problem: 2 Solution: 3 Method: 1
Gerwin (1982)	Do's and Don'ts of Computerized Manufacturing	Source: 1 Problem: 2 Solution: 3 Method: 3
Gold (1982)	CAM Sets New Rules for Production	Source: 1 Problem: 2 Solution: 2 4 Method: 3
Hayes & Abernathy (1980)	Managing Our Way to Economic Decline	Source: 1 Problem: 1 Solution: 2 Method: 2

AUTHOR(S)	TITLE	CODING
Hayes & Garvin (1982)	Managing as if Tomorrow Matters	Source: 1 Problem: 2 Solution: 2 4 Method: 1
Hayes & Wheelwright (1984)	Restoring Our Competitive Edge: Competing Through Manufacturing	Source: 1 Problem: 1 Solution: 2 4 5 Method: 2
Hill & Dimnik (1985)	The Accountant's Role in Cost-Justifying New Technologies	Source: 3 Problem: 2 Solution: 2 5 Method: 2
Hodder (1986)	Evaluation of Manufacturing Investments: A Comparison of U.S and Japanese Practices	Source: 1 Problem: 3 Solution: 3 Method: 3
Huber (1985)	CIM: Inevitable, But Not Easy	Source: 2 Problem: 2 Solution: 2 4 Method: 3
Huber (1986)	Justification: Barrier to Competitive Manufacturing	Source: 2 Problem: 2 Solution: 3 4 Method: 2
Kaplan (1984a)	The Evolution of Management Accounting	Source: 3 Problem: 1 Solution: 1 2 Method: 1
Kaplan (1984b)	Accounting and Control Systems for the New Industrial Competition	Source: 3 Problem: 1 2 Solution: 1 3 4 Method: 1
Kaplan (1986a)	Must CIM Be Justified By Faith Alone?	Source: 3 Problem: 2 Solution: 3 4 5 Method: 2

AUTHOR(S)	TITLE	CODING
McDonald (1985)	Modern Systems Demand Fresh Look at ROI Concepts	Source: 3 Problem: 2 Solution: 4 Method: 2
McLean (1986)	Manufacturing: Competitive Edge or Corporate Millstone	Source: 3 Problem: 1 2 Solution: 2 Method: 1
Merchant & Bruns (1986)	Measurements to Cure Management Myopia	Source: 3 Problem: 1 3 Solution: 5 Method: 1
Pearson (1986)	The Strategic Discount -- Protecting New Business Projects Against DCF	Source: 1 Problem: 1 2 3 Solution: 2 3 Method: 1
Port (1987)	Making Brawn Work with Brains	Source: 1 Problem: 2 Solution: 4 Method: 2
Powell (1986)	Turning Costing On Its Head	Source: 2 Problem: 2 Solution: 4 Method: 2
Primrose, Bailey & Leonard (1984)	The Practical Application of Discounted Cash Flow to Plant Purchases Using an Integrated Suite of Computer Program	Source: 3 Problem: 2 Solution: 4 5 Method: 1
Rizzi (1984)	Capital Budgeting: Linking Financial Analysis to Corporate Strategy	Source: 1 Problem: 2 Solution: 4 5 Method: 1
Sheridan (1986)	How to Account for Manufacturing	Source: 1 Problem: 1 2 3 Solution: 1 2 3 4 Method: 2

AUTHOR(S)	TITLE	CODING
Sullivan, W.G. (1986)	Models IEs Can Use to Include Strategic Non-Monetary Factors in Automatic Decisions	Source: 2 Problem: 2 Solution: 3 5 Method: 1
Utecht (1986)	Need Help Justifying Automation?	Source: 2 Problem: 2 Solution: 2 4 Method: 2

APPENDIX B: INVITATIONS SENT TO GMC SUPPLIERS

1. Letter of invitation from GMC

2. Information Sheet

3. Response Sheet

GM

General Motors of Canada Limited

May 28, 1987

I am writing this letter to ask you to participate in a research study.

Mr. Tony Dimnik, a doctoral candidate at the School of Business, University of Western Ontario, is studying General Motors parts suppliers. The purpose of the study is to develop accounting and control systems that promote efficiency and innovativeness.

I think the results of the research will be of interest to you and to us.

Information about your company will be held in the strictest confidence. General Motors and the participants in the study will receive only general statistical summaries of the results. All participants in the study, including General Motors, will receive the same summary report of the findings.

Attached are an information sheet about the project and a response sheet. Although not mandatory, we would appreciate your participation in this study. If you elect to participate, please fill in the response sheet and return it in the envelope provided.

If you have any questions, please telephone Mr. Dimnik at (519) 679-2111, extension 5184.

Thank you.

Yours truly,

Bill

W.F. (Bill) Eagen
Director of Purchasing

:bd
Attachs.

215 William Street East Oshawa Ontario L1G 1K7

The University of Western Ontario

DOCTORAL PROGRAM RESEARCH
School of Business Administration
London, Canada
N6A 3K7

INFORMATION SHEET

Promoting Innovation and Efficiency with Management Accounting and Control Systems

The study focuses on four groups of suppliers to General Motors of Canada:

1. Large/Medium Metal Stampers
2. Thermoplastic Injection Molders
3. Rubber Parts Manufacturers
4. Functional and Decorative Die Casters

We have chosen 6 representative plants from each group for a total of 24 plants.

The managers of these 24 plants will receive questionnaires which should take less than one hour to complete. Mr. Dimnik will visit the plants to pick up the questionnaires and to conduct interviews with the plant managers. Interviews should take less than 90 minutes.

Data from the questionnaires and interviews will be summarized and interpreted in a report which will be sent to General Motors and to all participating suppliers.

The data will also be used in a PHD thesis and in articles in academic and management journals.

The information from each plant manager will be held in the strictest confidence. No information that could identify any individual plant or manager will be released to anyone, including General Motors. Results will be reported only as statistical aggregations.

RESPONSE SHEET

We need the name of the plant or manufacturing manager for PLANT NAME The person selected for the study should meet the following criteria:

1. The person should be someone who makes capital budget proposals to top management but does not have authority to approve them.

2. The person should be responsible for the operation of the plant.

Please print the name, telephone number and address of the plant or manufacturing manager who will participate in the study:

NAME: ______________________________

TITLE: ______________________________

PHONE NUMBER: ______________________________

MAIL ADDRESS: ______________________________

____

____

____

____

Mr. Dimnik will contact the person named above.

Please print your name and title:

____

____

Please return this sheet in the envelope provided.

Thank you.

APPENDIX C: MAIL QUESTIONNAIRE DOCUMENTS

1. Questionnaire Cover Letter

2. Questionnaire Instructions

The University of Western Ontario

DOCTORAL PROGRAM RESEARCH
School of Business Administration
London, Canada
N6A 3K7

DATE

NAME
TITLE
COMPANY NAME
ADDRESS
ADDRESS
POSTAL CODE

Dear

You are one of a small group of managers that has been selected for a study of efficiency and innovation in the automotive industry. CEO NAME suggested your name to us.

Plant managers of current and potential suppliers of parts to General Motors of Canada have been sent copies of the enclosed questionnaire. The questionnaire will be followed up by personal interviews.

Because only a small sample of managers has been selected for this study, it is important that you complete the questionnaire and return it in the envelope provided.

The information from each manager will be held in the strictest confidence. No information that could identify any company or any manager will be released to anyone, including General Motors. Results will be reported only as statistical aggregations.

When the project is completed you will receive a copy of the report sent to General Motors. I will also give you a complete explanation of the research when we meet in the next few weeks.

I would be most happy to answer any of your questions. My telephone number is (613) 545-2315.

Yours truly,

Tony Dimnik
Doctoral Candidate

Instructions

This questionnaire should take less than one hour to complete. Most of the questions can be answered simply by circling a number.

If you don't understand a question or can't answer it, please leave it blank and put a question mark (?) in the margin.

Questionnaire responses will be followed up with personal interviews later in September.

Data from the questionnaires and interviews will be summarized and interpreted in a report which will be sent to General Motors and to all survey participants. The data will also be used in a PhD thesis and in articles in academic and management journals.

The information you give me will be held in the strictest confidence.

Each questionnaire has an identification number for mailing purposes only. This is so that I may check your name off my list when your questionnaire is returned. Your name will never be placed on the questionnaire itself.

No information that could identify you or your company will be released to anyone, including General Motors. Results will be reported only as statistical aggregations.

Please complete and return the questionnaire as soon as possible.

APPENDIX D INTERVIEW PROTOCOL

This interview will have two parts. First I will ask you some questions and then I'll explain what we're hoping to accomplish with this study.

As I stressed in my earlier correspondence, anything you say to me will be held in the strictest confidence. No one will be able to identify you or your company.

I would like to tape-record our session. I will be the only person to listen to the tape. I find tapes helpful in making sure I have the correct information, but I won't use the recorder unless you feel comfortable with it. May I use the recorder?

Do you have any questions before we start?

I'll begin by asking you some questions about the flexible automation technologies you use in your plant.

[FOR EACH OF THE FOLLOWING ASK:]

Does your plant have....
How is the technology used?
How long has the technology been in place?
Has it been successful?

Industrial Robots

Programmable Controllers

Numerically controlled machines (NC) ...

Computer controlled NC machines (CNC)...... . ...

Computerized material handling equipment.. ......

Computer-aided inspection and testing devices........

Computer-aided design (CAD).

Integration between CAD and computer-aided manufacturing (CAD/CAM)..................

Do you think your plant could use more flexible automation?

[IF SAY YES, PROBE] What's holding you back?

- top management
- accounting system
- other reasons

Are you ever frustrated when you want to buy some new machinery or equipment and can't get approval?

I would like to talk about your latest purchase of flexible automation What is the newest flexible automation equipment in your plant?

When was it purchased?

Whose idea was it to get it?

Did the equipment purchase have to go through a formal approval process? Describe that process....

[PROBE]

- did anyone have to do a formal financial analysis
- role of accountants in process (any conflict)
- plant manager's role in process
- top management role in process (top down/bottom up)

Was this purchase of machinery typical? How does it differ from norms?

Are capital investments in your plant required to exceed a certain rate of return or hurdle rate?

What is the hurdle rate? %

How important is hurdle rate in getting approval to buy new equipment?

Are some capital investments in flexible automation required to meet a different hurdle rate than other investments?

What is the hurdle rate for flexible automation? %

Has the hurdle rate changed in the past few years?

Does it change with inflation rate?

Is there a required payback period for capital investments in your plant?

What is the required payback? years

Are some capital investments in flexible automation required to meet a different payback period than other investments?

What is the payback period for flexible automation? years

Has the payback period changed in the past few years?
Does it change with inflation rate?

[HAND OVER CARD AND ASK TO COMPLETE WHILE EXPLAINING CHOICES]
Please explain choices as you go along....

What do you think counts the most in how your boss evaluates your performance?

Put the number 1 next to the item you think counts the most.
Put the number 2 next to the item that counts second most.
Put the number 3 next to the item that counts third most
Finally, put the number 4 next to the item that counts fourth most

--- How well you cooperate with co-workers

--- Your concern with costs.

--- How well you get along with your boss

--- How much effort you put into your job.

--- Your concern with quality.

--- Meeting the budget.

--- Your attitude toward your work.

--- Your attitude toward your company.

--- Your ability to handle your workers.

--- Your ability to keep your customers happy

--- Other________________________________

[PROBE] Are there any items on the list that should be there?

[PROBE] What do you see as the difference between 'concern with costs' and 'concern with budget'?

In the last question we talked about your boss...who is your boss?

Name

Title

How long has your boss been in his job? years

Any changes in the way you are evaluated in past few years?
[PROBE IF EVALUATION CHANGE WITH CHANGE IN BOSS]

Let's talk a bit about your job....How do you define your job?
[PROBE DUTIES, AUTHORITY, PROFIT/COST/INVESTMENT CENTER?]

How far ahead do you plan?

What sort of information do you keep track of so that you know what's going on in your plant?

Do you keep your own personal records to make sure everything's going well?
[PROBE]

- what information
- what form (pencil/paper, computer, etc.)

How important is accouting information for you?

- for evaluating your workers
- for making decisions
- to know what's going on

Are you satisfied with the financial information you're getting?

Are you satisfied with the way the financial information is being used by your superiors, by co-workers?

Please give me a description of your manufacturing process
[PROBE: TYPE OF PROCESS
BATCH SIZE
INVENTORY LEVELS
TYPE OF MATERIAL USED
TYPE OF LABOR USED (SKILLED OR UNSKILLED)]

Can you give me a rough idea of your costs...For your major products, what percent of your total costs are:

----- raw materials

----- labor

----- overhead

What are the key success factors for your plant? What do you have to do well to be successful?

APPENDIX E: INTERVIEW CODING SHEET

ID-GROUP-PLANT

number of robots	___robnum
earliest date of adoption in months (October-0)	___robtim
success of robot applications (1-none 2-some 3-lots 9-unknown)	___robsuc
number of programmable controllers	___connum
earliest date of adoption in months (October-0)	___contim
success of PC applications (1-none 2-some 3-lots 9-unknown)	___consuc
number of CNC machines	___cncnum
earliest date of adoption in months (October-0)	___cnctim
success of CNC applications (1-none 2-some 3-lots 9-unknown)	___cncsuc
use of computerized material handling (none-0 some-1)	___matuse
earliest date of adoption in months (October-0)	___mattim
success of material handling (1-none 2-some 3-lots 9-unknown)	___matsuc
use of computerized inspection (none-0 some-1)	___insuse
earliest date of adoption in months (October-0)	___instim
success of comp inspection (1-none 2-some 3-lots 9-unknown)	___inssuc
use of CAD (none-0 outside-1 head-office-2 onsite-3)	___caduse
earliest date of adoption in months (October-0)	___cadtim
success of CAD (1-none 2-some 3-lots 9-unknown)	___cadsuc
integrated computerized manufacturing (none-0 some-1)	___camuse
earliest date of adoption in months (October-0)	___camtim
success of CAM (1-none 2-some 3-lots 9-unknown)	___camsuc
could use more FA (0-no 1-lukewarm 3-positive 5-enthusiastic)	___morefa
frustrated in proposals (0-no 1-some 2-yes)	___frustr
payback on FA (in months)	___TMHOR3F
payback important (no-0 some-1 very-2)	___EMFJST2F

budget constrained-4
budget/profit-3
profit-2
non-accounting-4 ___EMFEVL1F

respondent level (1-low 2-middle 3-upper) ___MANPOS1

responsible for sales (1-no 2-some 3-yes) ___MANPOS2

Job Definition

____

____

satisfied with financial info (0-no 1-quite 2-very) ___satfin

raw materials (% of total costs) ___matcos

labor (% of total costs) ___labcos

overhead (% of total costs) ___ovrcos

Key Success Factors

____

____

visited/not-visited plant (0-no 1-yes) ___vispla

[FROM PLANT TOUR]
low flexible automation--(1 to 5)--high flexible automation ___ADOP5F

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