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**Transfer of Advanced Manufacturing Technologies from
Universities to Industry: An Industry Perspective**

by

Mr. M. Johnny Rahil, B.A. Accounting

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

School of Business
Carleton University
Ottawa, Ontario

December 9, 1992

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ABSTRACT

This study focuses on the relationship between universities as inventors of advanced manufacturing technologies (AMT's), and industrial firms as either commercializers or users of the technologies. It investigates the effect of company size on its incentives for and barriers to the transfer of AMT's from universities. It also examines other issues related to the AMT transfer process, such as methods of establishing contact, methods of knowledge transfer, criteria used to judge the success of the transfer, and role of intermediary organizations.

Interviews with fifteen companies indicate that incentives for transfer do not seem to vary with size, whereas some barriers to transfer do. Subjective data collected seem to better clarify the effect of size on companies' incentives and barriers than objective data. Results show that companies are more proactive than universities in establishing contacts. They usually approach universities directly without resorting to intermediary organizations. Results also indicate that written documents and face-to-face conversations are the most frequently used methods for transferring the knowledge to adopter companies. Technical success seems to be more important to many companies than commercial success.

An investigation of the preceding issues in a larger sample will give a more precise idea about the relationships examined.

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CHAPTER I

INTRODUCTION

The Science Council of Canada, in its 1988 annual report, stressed the importance of the university-industry relationship through these lines:

"We need to integrate people, ideas, opportunities, markets and capital in new and effective ways. The most urgently needed linkages are those between the research community within the universities and the private sector. A new sense of strategic partnership must become a reality. If our goal of the 21st century is to have built in Canada a vigorous R&D base within the industrial sector, by revitalization and diversification of our existing and mature industries, and by creating spin-off firms and more advanced high-technology industries, then we have no option than to put our science and technology to work." (P.2)

In a series of eight discussion papers published between 1986 and 1987, the Science Council of Canada expressed concern that the amount of research and development conducted in Canada is considerably less than in other developed nations (Giles et al., 1989). It reasoned that since Canada has a proportionately small industrial base to carry out such activity, it has to rely on its universities to supply a large part of the technological innovations.

The 1985 Annual Report of the Ministry of Science and Technology discussed that only a small portion of the world's technological advances are actually made in Canada (Gerwin et al., 1990). It argued that diffusion of such inventions should take place rapidly in order for Canada to maintain and improve its competitive position in the international market. The slow, incomplete, or unsuccessful transfer of inventions

from university laboratories to the industrial sector is a major concern.

The way the university-industry relationship is approached reflects on international competitiveness. Canada's Free Trade Agreement (FTA) with the U.S. adds urgency to the issue of Canada's technology base, and therefore, to the issue of technology transfer (TT) from universities to industry. The trade agreement eliminates all tariffs and removes or relaxes a host of other barriers to the free flow of goods, services, and investment between the two countries over a ten year period starting January 1st, 1989 (Nolle, 1990). Consequently, all Canadian products must compete with American products, not only in the U.S. and abroad, but also in Canada.

In an increasingly competitive world market, Canadian companies are under pressure to design better quality, greater function, and lower cost products. Advanced Manufacturing Technologies (AMT's) are an important means for achieving that goal. Knowledge and manufacturing techniques developed in universities can help alleviate some problems experienced by the Canadian industry in this respect.

This study investigates the Canadian industry's perspective of the AMT transfer process from universities. It is designed to complement the work of a Carleton University

research team, Gerwin, Kumar, and Pal (1990)¹, who investigated the Canadian universities' perspective of this transfer process. It is hoped that the results of this study would help bring the two bodies, the Canadian universities and the Canadian manufacturing sector, closer together.

The study's primary focus is on the effect the company size has on its barriers to and incentives for AMT transfer from universities. Once those barriers and incentives are identified for companies of different size, they can be used by universities, government, and industry in establishing AMT transfer policies. Institutions like government bodies and universities need to know which are the most important manipulable variables they can influence in their AMT transfer policies and strategies.

A few researchers (e.g., Boyle 1986² and Schlie 1987³) have discussed the issue of company size as related to

¹A version of this study is also published in the Journal of Technology Transfer, 1992, vol.17, no.2.

²Boyle (1986) surveyed 20 collaborator and non-collaborator different size companies in the U.K. offshore oil exploration industry regarding their adoption of technologies from universities. He discussed the factors which encourage industry to participate in joint projects with universities, the barriers impeding such collaboration, and means of overcoming these barriers.

³Schlie (1987) reviewed the literature regarding manufacturing technology transfer from universities to industry in the United States. He discussed concepts, models, and definitions of technology transfer. His review covered studies that examined companies' barriers to and incentives for transferring technologies from universities and mechanisms of transfer.

companies' incentives and barriers to transfer. These studies, however, were not conducted in Canada, and did not concentrate on AMT transfer. In this study, the size issue will be investigated in the context of AMT transfer from Canadian universities. Therefore, this study hopes to improve the understanding of the current process of AMT transfer from universities to the manufacturing industry in Canada, while concentrating on the influence the company size has on its incentives for and barriers to transferring AMT's from universities.

The investigation has been conducted through interviews with representatives of selected companies that have attempted AMT transfer(s) from Canadian universities. Most of the companies are located in Ontario, where over half of the country's manufacturing goods are produced, and has more robots, computer aided manufacturing, flexible manufacturing systems, and other advanced manufacturing technologies than all other provinces combined (Loo, 1987). From this standpoint, the study's results can be taken to reflect the Canadian manufacturing scene, in general.

The thesis is organized in four chapters. Chapter II reviews the literature related to technology transfer from universities to industry. A large part of the research on technology transfer has been conducted outside Canada, and few have an AMT focus. Thus, the review emphasises issues related to technology transfer in general, with a concentration on AMT

transfer where possible. Also, the review covers technology transfer research that was conducted outside and inside Canada.

Chapter III elaborates on the research objectives, and outlines the data collection procedures and methods used to analyze the data.

Chapter IV discusses the study's results and contributions and compares them with those of the Gerwin et al. 1990 study. Recommendations to government, universities, industry, and future research directions are also made.

CHAPTER II

LITERATURE REVIEW

This chapter provides a rationale for the current study as well as an overview of the literature. Beginning with a discussion of technology transfer and advanced manufacturing technology characteristics, this chapter highlights the barriers to and incentives for technology transfer from universities, mechanisms of transfer, knowhow transfer, methods of establishing contacts, and criteria used by companies to judge the success of the technology transfer project.

2.1 TECHNOLOGY TRANSFER

2.1.1 Technology Transfer Definitions

Technology has been defined by Schon (1967) to be the body of practical knowledge, techniques, and equipment that people use to enhance their control over natural forces and to enlarge their work power and ability to overcome constraints. Technology transfer, then, is the process by which those techniques and knowledge are diffused throughout human activity (Bradbury et al., 1978). It is the process that enables one group of people (receiver) to receive technology from another group (sender).

Certain conditions should prevail within the source and the receiver in order to pave the way for a successful technology transfer (Gee, 1979). For instance, the source

should possess technical knowledge and technical capability that could be useful to the receiver. Also, the source must understand the needs and limitations of the receiver. The receiver should have complementary knowledge and capability, understand the potential contributions of the source, and demonstrate interest and support (Gee, 1979).

Gee (1981) views technology transfer as the process by which technology developed for one purpose is employed in a different application or by a new user. This definition, however, excludes vertical technology transfer. A more comprehensive definition is that of Brooks (1966) who considers technology transfer as the "movement of technology" through transformation of basic scientific knowledge into technology, or through adaptation of an existing technology to a new use. These transformations have been respectively referred to by Brooks (1966) as "vertical" and "horizontal" technology transfer.

An example of horizontal technology transfer is Marco Polo's introduction of chinese inventions (e.g., compass, papermaking, printing, and the use of coal for fuel) to the western world (Gee, 1981). The example shows that technology transfer is not a new concept. However, it is only recently that systematic efforts were made, in some industrial countries, toward the vertical transfer of technology. These are attempts to expand the utilization of the existing science and technology bases (Gee, 1981).

Noori (1990) discusses technology transfer in five different contexts: international technology transfer, transfers from government to industry, transfers from universities to industry, interfirm technology transfer (between different firms), and intrafirm technology transfer (within the same firm). He defines horizontal and vertical technology transfer in the context of intrafirm technology transfer, where horizontal transfer is seen as the transfer of technology across different divisions of the same firm, and vertical transfer is viewed as "the transfer that occurs during the innovation process, such as from research to development to application" (Noori, 1990, p.122).

The current study investigates vertical transfer of advanced manufacturing technologies from universities to industry. It views universities as the source, industry as the receiver, and technology as the link.

2.1.2 Contributions of government and universities to technology transfer in Canada

Canadian universities are a major source of knowledge and expertise that can help industry solve many of its problems. Noori (1990) notes that in different countries, different levels of cooperation exist between government, university, and industry. In Canada, the highest alliance is between the government and universities. In the United States, industry and university are closely allied and in Japan, strong

cooperation exists between industry and government. Therefore, in a country like the United States, technology transfer from universities might be easier than that in Canada due to the close relationship that prevails between universities and industry. Noori (1990) argues that countries with better alignment of goals of university, industry, and government systems will command a competitive advantage.

The Science Council of Canada (1987, proceedings) reported that half of Canadian R&D is sponsored by the governments and universities, largely because of the low level of private sector spending. The 1989 Ontario Premier Council's Report mentioned that one quarter of R&D conducted in Canada is performed by universities. It pointed out that Canada's low industrial R&D spending ranks significantly below that of the United States and is much less than that of Japan, West Germany, United Kingdom, and France.

As a result of low industrial R&D spending, many programs are being offered by the Canadian government to support it. For example, the National Research Council's (NRC) Industry Research Assistance Program (IRAP) supports small- and medium-sized companies both technically and financially. It provides them with information about Canadian expertise, and assists them in developing products or processes that have commercial potential.

Another important program is the Ontario Technology Fund that helps the province of Ontario move to the forefront of

scientific leadership and technological innovation. One of the program's important contributions is the University Research Incentive Fund (URIF) that encourages universities and the private sector to enter into cooperative, contract-based, research projects. This program also enables many university departments and labs to acquire advanced equipment that can be used for new research once the URIF project is completed.

Government labs also perform a major part of the country's R&D. However, they do not substitute for university labs because of their structure and mandate. They are not suitable for high-risk advanced technology startups such as university spin-offs, and are more bureaucratic than university labs (Science Council of Canada, 1987). Further, universities are better able to disseminate research results than government labs (Noori, 1990). Universities spread research results not only through publications, but also through students.

2.1.3 The Gerwin et al. (1990) study

Gerwin et al. focused on the processes through which the advanced manufacturing technologies (AMT's) have been transferred from universities to the manufacturing industry in Canada. Their study illuminated the university side of the issue. A discussion of the study's theme and methodology will, therefore, be appropriate. Its contributions will be

discussed throughout this thesis.

Interviews, based on a short-answer (open-ended and close-ended) questionnaire, were conducted with sixteen professors active in technology transfer, six university-industry liaison officers, and seven administrators in several intermediary organizations that match research with industry needs. The issues discussed in the study included universities' incentives for and barriers to AMT transfer, methods of establishing the contact, methods of knowhow transfer, and criteria used to evaluate the projects' success.

One of the Gerwin et al. (1990) recommendations for improving the effectiveness of the AMT transfer was that government policies should promote AMT transfers from universities to companies, especially small companies. Also, they suggested that funding programs should encourage joint work on the integrations of AMT as it is considered to be the wave of the future. Other suggestions covered the need for universities to shorten the lead time for considering potentially commercializable inventions, the need for universities to become more proactive in establishing the contact, and the necessity of establishing long term relationships between companies and universities.

Gerwin et al. (1990) concluded that collaborative projects between industry and universities can help in alleviating some problems of Canadian manufacturing. A large part of this assistance can come through upgrading and

developing the country's advanced manufacturing technologies.

2.2 THE ADVANCED MANUFACTURING TECHNOLOGIES

Gerwin et al. (1990) defined AMT's to be "a family of techniques used in product design, the production process, manufacturing planning and control, and in integrations of these three areas. They can be readily adapted to a variety of uses through computer programming, and perform a significant part of their functions without direct human intervention. They may consist of hardware, software, or some combination." (p.2) This study will use the same definition. (Appendix 1 details the technologies considered to be AMT's.)

In this study, focus will be on discrete part manufacturing, which refers to fabrication or assembly of metallic, electronic and other components. Discrete manufacturing is chosen because this is where the "AMT's impact is the greatest at the moment" (Gerwin et al., 1990, p.2). Countries which are leaders in the use of such technologies will become competitive in more than one industry (Loo, 1987). The survival of the Canadian manufacturing industry rests upon its ability to adopt these new technologies. Currently, it lags behind industries in Japan and the United States by two to three years in this respect (Donnelly, 1988).

Donnelly (1988) notes that the current trend in manufacturing is towards automated factories in which the

entire manufacturing process is integrated and controlled by a central computer. He argues that AMT's have the potential for enhancing a company's productivity and the product quality while reducing the production cost and the lead time. He also cites cases where AMT's have been used to improve flexibility, quality and speed of manufacturing operations while reducing the need for economies of scale.

With traditional equipment, manufacturing greater volumes results in lower unit costs (economy of scale). Larger volumes allow for the use of special-purpose equipment, the cost of which is only justified by large-scale operations (Loo, 1987). AMT's, on the other hand, result in lower unit production cost regardless of the production volume.

Flexibility of some advanced manufacturing technologies allows quick changes in product design in response to market needs. When demand changes, machines can be set up easily to manufacture different kinds of products in desired volumes. Products can enter the market in shorter time and in needed volumes. Also, the quality of the product and speed of production are usually higher with AMT's than with traditional equipment, mainly because of the reduction in human involvement (Loo, 1987).

Improved quality, higher speed and flexibility attract companies to the use of advanced manufacturing technologies. However, adoption and installation of AMT is not easy (Bryan, 1989). Usually, major capital expenditures are needed to

install and integrate an AMT in a factory. In addition, successful AMT applications often require a strategy for technological, structural and cultural change within the company (Bryan, 1989). Further, most systems depend on trained and motivated personnel. The advanced technologies fail when motivation or training is lacking (Allegri, 1989).

In Canada, the difficulty of AMT adoption is intensified because "Canadian manufacturing firms are slow adopters of advanced manufacturing technologies" (Loo, 1987, p.17), lagging behind other industrialized nations in this respect. Loo argues that the major problem lies with the traditional capital budgeting tools used to measure the desirability of AMT's. These techniques and their misapplication often result in estimations of costs that are biased against the adoption of AMT's.

Another factor that makes the transfer of technologies from universities to the manufacturing industry difficult, is the nature of that industry. Some industries are more dependent than others on universities for their products (Science Council of Canada, 1987, proceedings). For example, the biotechnology industry is more dependant than the manufacturing industry on universities. This dependency makes the transfer of technology to such industries easier. Also, in some of these industries, unlike manufacturing, research can have immediate commercial potential which makes it easier to transfer (Bremer, 1985).

There is a major need for Canadian companies to adopt and install AMT's. Canadian universities can be of major help as suppliers of AMT's. However, most transfers of AMT from universities to industry in Canada are slow, incomplete, or unsuccessful.

2.3 MECHANISMS OF TECHNOLOGY TRANSFER

In this study the industry's views about mechanisms of technology transfer (TT) will be sought, and therefore, it is important to understand how they function. There are several mechanisms to transfer technology from universities to industry. No one mechanism works for all TT attempts and more than one mechanism can be used in the same attempt. Naturally, many innovative ideas have sprung up and have been tried. Different mechanisms have been used with varied degrees of success. These mechanisms include: direct professor-firm links (Gerwin et al., 1990), contract research (Baldwin, 1986 and Potworoski, 1988), exchange programs (Baldwin, 1986; Kendrick, 1982; Gerwin et al., 1990), research consortia (Smilor et al., 1991 and Murphy, 1990) co-operative research centres (Powers et al., 1938; Furino et al., 1990; Science Council of Canada, 1987; Guelph University Alumni Newsletter, 1992) industrial liaison centres (Gerwin et al., 1990), and spin-off companies (Giles, 1989 and Gerwin et al., 1990).

1) Direct Professor-Firm Links

In some instances, a professor directly contacts a firm which might be interested in his or her invention (Gerwin et al., 1990). In other occasions, a firm approaches a professor on the basis of its past relationship with him or her, or of peers' recommendations. The latter mode of transfer (i.e. professors being approached by firms) was reported to be more popular (Gerwin et al., 1990). Typically, companies approached labs with their problems, and funding was arranged through research contracts or government sponsored joint industry-university programs. One significant problem of this mode is that it prevents widespread circulation of the invention (Gerwin et al., 1990).

2) Contract Research

A large majority of TT projects are carried out by university professors with funding provided by industrial firms under a research contract (Baldwin, 1986). Potworoski (1988)⁴ defines a research contract as "an agreement between two corporate bodies, namely, the company and the university,

⁴Potworoski (1988) surveyed R&D executives from fourteen Canadian companies regarding their practices to manage the transfer of technology from universities. The companies were of different sizes and from more than one industry. His study focused on the measures used by companies to transfer technology from universities, as well as the principles that should be followed in order to obtain successful R&D links with universities. Definition of the research contract was also one of the important issues discussed.

to provide financial support for an investigator or a group of investigators, to conduct research in a particular field under specific stipulations and conditions." (p.58) He reports that the contracts often:

- specify the scope and nature of the research,
- set the time period(s) for a sequence of activities,
- define the deliverable(s),
- establish ownership, patent rights and licensing arrangements,
- establish budgets and payment schedules,
- provide for confidentiality of information supplied and created, and
- limit liability of participants.

Definition of the research contract depends to a large extent on the type of the research conducted. For example, its hard to specify the deliverables with exploratory research (Potworoski, 1988). However, the main objectives can still be stated.

3) Exchange Programs

In these programs, scientists from the industry participate in universities' research labs and faculty members work in industry for a length of time during which they can become aware of the commercial value of their research and obtain ideas for research (Baldwin, 1986). Thus, exchange programs provide faculty with access to current technical and production problems and keep industry in touch with new research. All parties benefit (Kendrick, 1982). An example of such a program in Canada is the co-operative research and

development program at McMaster University (Gerwin et al., 1990).

4) Research Consortia

Consortia are often composed of companies (shareholders), that seek mutually beneficial co-operative research while remaining competitors in the market place (Smilor et al., 1991). Companies pay a membership fee to participate. In return, they are given access to the results of the research. Privileges of the member companies include: a royalty-free license to use or sell any of the inventions, early access to the research results, and a share of royalty income derived from non-members' use of any research result. Examples of consortia arrangements in Canada are the Manufacturing Research Corporation of Ontario (MRCO), PRECARN Associates Incorporated, and Canadian Semiconductor Design Association (CSDA).

A research consortium provides an opportunity for a university to cooperate with a number of companies in different areas. Researchers benefit from the companies' financial support and from the built-in feedback that provides direction to their activities (Murphy, 1990).

5) Research Centres

Research centres are frequently located on university campuses. In many of these centres, members of both the

university and industry work together on researching ideas and developing inventions. Many universities establish research centres so that university-based researchers can explore questions posed by corporations, on the understanding that most direct costs will be paid by the corporations themselves (Powers et al., 1988).

However, establishing and maintaining a research centre is not an easy task (Furino et al., 1990). It takes major effort on the part of the academic and non-academic staff to build and maintain the needed level of support, participation, and cooperation. In Canada, the Geotechnical Research Centre at McGill University (Science Council of Canada, 1987, discussion paper) and the Guelph University Research Centre (Guelph University Alumni Newsletter, 1992) are such centres.

6) Industrial Liaison Offices

Most universities maintain a liaison office. Its mandate is to act as a link between the university and industry, informing the university about industry needs and problems, and supplying industry with information about recent technological developments in the university. Liaison offices often help in making contacts and in securing research funds from industry (Gerwin et al., 1990).

7) Spin-Off Companies

University spin-off companies "owe their origin to

university research or expertise" (Giles, 1989, p.11). They may be formed by faculty, staff, or students who wish to utilize the knowhow acquired through research at the university to produce goods or services for commercial purposes. Alternatively, these companies can come into existence through direct licensing of a product or process (Giles, 1989).

In the Gerwin et al. (1990) study, most of the interviewees believed spin-offs to be risky, time consuming and require business acumen that many of them did not have. They considered this method a last resort, to be employed when a company willing to license the technology could not be found.

The advantages of spin-offs, however, include opportunities for large financial gains, availability of government funding, and aid to potential technology users who want to deal directly with spin-off companies without having to go through a university's formal, and often bureaucratic, procedures (Gerwin et al., 1990). In Canada, the professors at the University of British Columbia (UBC) use this mechanism of transfer most often. Seventy three UBC spin-off companies have been formed in the last two decades (Giles, 1989).

Gerwin et al. (1990) report that Canadian universities use a number of the above mechanisms to transfer AMT's to the manufacturing industry. However, some mechanisms are more common than others. A professor, for instance, is more likely

to contact a company for transferring a technology than to set up a spin-off company, due to the difficulties involved in establishing and maintaining such a company.

2.4 INCENTIVES FOR TECHNOLOGY TRANSFER

The university and the company both benefit from a joint research and development project. The typical benefits to universities and industry are presented below.

2.4.1 Benefits to Universities

By collaborating with industry, universities obtain funding for research and development. They also benefit from "the useful contact with industrial scientists and from the exposure to problems of immediate industrial concern." (Schlie, 1987, p.105). Further, through this relationship, universities can identify potential licensees for new technologies, and graduate students can develop close relationships with prospective employers (Schlie, 1987).

Boyle (1986) notes that as a result of a reduction in government funding in the United States, U.S. universities are being forced to undertake research which is more commercial in nature. Such research might range from environmental issues to increasing efficiency and productivity in industry. He argues that this shift in focus of university-based research makes universities more popular to industry.

2.4.2 Benefits to Industry

By dealing with universities, a company can obtain a "window" on science and technology (by accessing current knowledge and research activities) and, at the same time, it can make use of university resources: skills, facilities and equipment (Baldwin, 1986). In addition, a company often enhances its image by enlisting the technical advances available in universities (Schlie, 1987).

In his discussion of the impact of company size in relationships with universities, Schlie (1987) argues that large companies may be too technologically advanced for universities to be of any help and small companies may be ill-prepared for such a relationship. However, he suggests that interactions can still benefit both parties.

2.5 BARRIERS TO TECHNOLOGY TRANSFER

Several studies have identified a number of barriers to technology transfer. Some of the major barriers are:

1) institutional differences (Schlie, 1987; Bremer, 1985; Boyle, 1986; Rizzuto and Cook, 1988), 2) information dissemination conflict (Boyle, 1986), 3) intellectual property rights (Useem, 1986), 4) communication barriers (Cooper, 1979; Useem, 1986; Donnelly, 1988), and 5) attitudinal barriers (Boyle, 1986). Each of these barriers will be discussed below.

1) Institutional Differences

Companies have one main goal in their operations: to maximize profit while minimizing their risks. Therefore, a focus on short term research occurs, as it gives a better chance for quickly accessing market opportunities, edging out competitors (Bremer, 1985). Universities, on the other hand, are interested in long term research. Their major objective is the creation and dissemination of knowledge (Bremer, 1985). Also, companies try to maintain secrecy of their operations; whereas universities willingly spread their knowledge through free and open operation. Further, universities conduct research mainly to gain knowledge for its own sake, while industrial research is directed towards obtaining specific knowledge for commercial applications (Rizzuto and Cook, 1988).

The fact that universities and industry are different in objectives and style seems to be a sufficient condition to make the transfer of technology difficult. Peters and Fusfeld pointed out that companies they surveyed in 1983 considered institutional differences to be one of the major barriers to cooperation with universities (Schlie, 1987). They found that the dissimilarities between university and industry objectives increased the opportunity for potential conflict. However, the university-industry relationship can work in spite of the differences involved. As Boyle (1986) argues, "both sides are not invariably incompatible...there are many examples of

universities conducting research which is directly linked to some industrial need." (p.36)

2) Information Dissemination

The rapid publication and dissemination of research results is the aim of university-based research. But, by postponing the publication of university research, when working jointly on R&D projects, the industrial partners maintain control over the research results for an extended period. Control of information is an advantage in a competitive market place (Boyle, 1986). Thus, cooperation with industry sometimes makes it harder for universities to share the research and can restrict their contributions to the broader economy.

3) Intellectual Property Rights

The issue of ownership of intellectual property rights (established through patents, disclosures, licenses, etc.) has been an impediment to the performance of joint work in many projects (Useem, 1986). All involved parties work on ensuring that their interests are fairly protected. However, these interests are often in conflict.

4) Communication Barriers

One of the major hindrances to TT is the communication barrier. The communication gap is often caused by industry's

low awareness of university research, universities' little knowledge of industry needs, and the difficulty of keeping abreast of new developments on both sides (Useem, 1986). Also, Cooper (1979) suggests that some companies, mainly small, may not have the needed resources (such as, money or staff) to communicate with universities at an appropriate level. In Ontario, eighty percent of people at manufacturing plants have no university-level technical training (Donnelly, 1988).

5) Attitudinal Barriers

Boyle (1986) blames both sides for attitudinal misgivings. Academics often regard applied research as being inferior to basic research, while managers believe that universities still live in "ivory towers" and do not deal with real world problems.

It seems that the "not invented here" syndrome is very common in industry. This refers to a company's resistance to adopting inventions coming from outside the firm (Boyle, 1986). Boyle reported that most of the large companies considered this syndrome to be the most influential barrier to their collaboration with universities.

Other barriers have also been identified in the literature. For example, professors interviewed by Gerwin et al. (1990) indicated that lack of funding for continued development of the technology and lack of expertise in liaison

offices were major barriers to AMT transfer from universities. Company representatives interviewed in the Potworoski study (1988) identified poorly defined research contracts as a major barrier to transfer.

Company size was viewed as a barrier to transfer by several researchers (Cooper, 1979; Gieser and McDonald, 1987). Size impacts the company's approaches and methods of making decisions (Office of Industrial Innovation, 1986). Therefore, it might affect the company's decision to cooperate with universities. A small company's cooperation with universities might be obstructed by its lack of resources or the university's bureaucracy.

Cooper (1979) and Gieser and McDonald (1987) suggest that collaboration between small companies and universities in the technology transfer area is difficult. Small companies do not usually have the resources to utilize or support university research. Universities might also be too bureaucratic for them. Cooper (1979) observes that major research universities can more easily create publicly visible research partnerships with large companies than with smaller firms. He argues that "in spite of the fact that smaller firms tend to be more innovative and ready to seek out new scientific opportunities than larger ones, they are ill-prepared to support the research so necessary for their own longer-term survival" (p.29).

Yet, McHenry (1985) argues that "cooperative research and

technology transfer is a game everyone can play. Size of the industrial firm is not a barrier to success. In spite of the difficulties of partnership between smaller companies and universities, the need for establishing and strengthening it is large." (p.9) He suggests that small companies should get involved in partnerships that help them upgrade their technologies continuously. This is perhaps their only way to survive and prosper.

It seems that small companies face more problems in their cooperation with universities. This might make them hesitant or unable to adopt technologies developed on university campuses. However, they should try to get involved in a cooperative relationship which seems to be so necessary for their long term survival.

2.6 METHODS OF ESTABLISHING THE CONTACT

According to Gerwin et al. (1990) a successful transfer depends to a large extent on the method used to bring together university professors and interested companies. Circumstances that give rise to a university-industry collaboration very likely affect the role that both parties play in a transfer process and the outcome of that transfer. Boyle (1986) argues that if a company is approached by a university to participate in a joint project, the company would more likely have an advisory role. On the other hand, if a company initiates the relationship, because of a reason, such as a lack of R&D

capability, it will get more involved in the project and concentrate on potential commercial gain.

Gerwin et al. (1990) indicated that contacts were usually established through reactive or proactive modes. From a university perspective, if the reactive mode is used, the university usually waits to be approached by a company or an intermediary organization. If the proactive mode is used, the university initiates the contact. Therefore, if proactive and reactive measures are discussed from a company perspective, it is expected to "hunt" for the technology by approaching the professor or the university in the proactive mode. If the reactive mode is used by the company, it usually waits for contact with universities to happen by chance. It waits to be approached by "somebody", whether it is the inventor, the university, or an intermediary organization.

2.7 KNOWLEDGE TRANSFER

Technology transfer involves more than the physical transfer of a software or hardware. It also involves transferring the knowledge embedded therein. This is a critical factor without which the technology transfer would be incomplete.

Gerwin et al. (1990) view knowhow transfer as conveying knowledge about how to use a technology. Several methods were used by professors interviewed in the Gerwin et al. (1990) study to transfer knowledge to companies. These methods

included written reports, face to face conversations, graduate students, and "how-to" manuals.

More than one method can be used to transfer the knowledge to a company. However, the company should have complementary knowledge and techniques in order to facilitate the technology transfer, and make the best use of the transferred knowhow (Gee, 1981).

2.8 SUCCESS CRITERIA

It is essential that universities and companies use some measures to estimate success of transfers. These measures may include technical measures as in the utilization of a technology and in meeting technical specifications, and commercial measures in terms of financial gains. Effect of a project on the long-term relationship between a company and a university is also an important measure for estimating the project's success.

In the study conducted by Gerwin et al. (1990), professors at the surveyed universities did not use systematic evaluation procedures to measure a project's success. They viewed success from a technical perspective, with little concentration on financial rewards and long-term relationships.

There is no reason to believe that companies' evaluation procedures would be any more systematic. Their success criteria would typically be derived from the reasons for

initiating the collaboration with the university (Boyle, 1986). Boyle feels that the higher a company's need for a transfer, the more involved it will get and the more it will concentrate on commercial success.

2.9 SUMMARY

Universities represent a relatively untapped national R&D resource that should be utilized in the best interest of the country. Universities' single role as disseminators of information is already changing and the pressure to participate in technology transfer is intense. The Science Council of Canada (1987) assures that university-industry collaboration in the technology transfer area is a responsibility essential to the process of economic growth in Canada.

Incentives for transferring the advanced manufacturing technologies are available for both the university and industry. Universities benefit from useful contact with industrial scientists and from funds they supply them with to conduct research. Industry accesses expertise, current knowledge, and advanced equipment available on campus. However, the transfer of AMT's is not an easy process. It requires a lot of time and effort. Major capital expenditures usually need to be made and a strategy for cultural and structural change needs to be adopted. In the case of transfer of AMT's from universities to the manufacturing

industry in Canada, the difficulty is intensified by the fact that Canadian manufacturing firms are slow adopters of AMT's (Loo, 1987). Institutional and attitudinal differences, information dissemination problems, and conflict over ownership of intellectual property rights all add up to the problems attached with AMT transfer from universities.

Various mechanisms can be used to achieve this transfer. These mechanisms include: direct professor-firm links, exchange programs, contract research, research centres, liaison offices, research consortia, and spin-off companies.

Some researchers believe that companies' incentives for and barriers to technology transfer from universities differ with company size. For example, Cooper (1979) and Gieser and McDonald (1987) believe that small companies' cooperation with universities is difficult. However, McHenry argues that in spite of the difficulty involved in such a cooperation, it enables small companies to upgrade their technologies, and is very necessary for their survival.

The issue of size has not been investigated in the context of AMT transfer from universities to industry. Also, issues like companies' criteria for estimating the projects' success and methods of knowhow transfer have not received enough investigation in the AMT area. These are some of the issues that will be investigated in this thesis in order to assist universities, government, and industry improve AMT transfer policies.

CHAPTER III

RESEARCH DESIGN

3.1 RESEARCH OBJECTIVES

This thesis studies the Canadian manufacturing industry's views of the process of AMT transfer from Canadian universities. It concentrates on the following issues: incentives for and barriers to AMT transfer, intermediary organizations, success criteria, evaluation of the technology, knowledge transfer, and methods of establishing the contact. Industry's views on these issues will be analyzed and compared to university's views as reported by Gerwin et al. (1990). Therefore, the study's broad objective is:

to improve the understanding of the current process of AMT transfer from universities to the manufacturing industry in Canada.

As has been discussed in the literature review, size is one of the important factors that affects technology transfer and attitudes towards technology transfer. Identifying companies' incentives for and barriers to technology transfer and differentiating them according to company size, form a strong basis on which government, industry, and universities can establish their technology transfer policies. Therefore, the study's specific objectives are to investigate:

1. the difference in incentives for transferring AMT's from universities as perceived by small and large companies, and
2. the difference in barriers to transferring AMT's from universities as perceived by small and large companies.

3.2 METHODOLOGY

The research used interviews to gather data about Canadian companies that have transferred AMT's from Canadian universities. The following sections describe how companies' participation was gained, how the sample was selected, and how the data collection and analysis were conducted. Different size companies were asked to participate in order to examine the effect of size on barriers to and incentives for transfer. But, company size can be measured in several ways. A discussion of size measurement is, therefore, appropriate.

3.2.1 Measurement of Size

The concept of size is not as easily operationalized as it first seems. Different measures have been used in estimating it. Some researchers (for example, Beamish and Munro, 1986; Craig and Beamish, 1989) used annual dollar sales and number of employees to indicate company size. Craig and Beamish (1989) classified Canadian manufacturing companies according to annual dollar sales. They considered small companies to be those with up to \$2 million in annual sales,

medium companies to be those with more than \$2 million but less than or equal to \$25 million, and large companies to be those with more than \$25 million.

Some others used number of employees or capital invested to determine company size. The National Research Council's (NRC's) Industrial Research Assistance Program (IRAP) uses number of employees to determine company size (Association of Provincial Research Organizations (APRO), 1991). It considers small companies to be those with up to 20 employees, and medium size companies to be those with more than 20 but less than or equal to 200 employees. Statistics Canada (1988) considers small companies to be those with up to 50 employees, medium size companies as those with more than 50 but less than or equal to 500 employees, and large companies to be those with more than 500 employees. Boyle (1986) considers small manufacturing companies to be those with up to 100 employees, medium size companies to be those with more than 100 but less than or equal to 500 employees, and large companies as those with more than 500 employees.

No classification scheme for size can be suitable for all industries. The classification of size categories depends upon the industry (manufacturing, service, etc.) in which the company exists. In the study by Mishima (1976), small and medium sized Japanese companies in mining and manufacturing industries were considered to be those with up to 300 employees. For service industry, small and medium companies

were classified as those with less than 50 employees. The study also used capital invested in the business to determine company size.

Small and medium sized enterprises are believed to share many common characteristics. They are "major contributors to the Canadian economy, being suppliers of products to large companies, incubators for new products and processes, and producers of customized products and services." (APRO, 1991, p.1). Not surprisingly, in a 1991 publication, the Association of Provincial Research Organizations (APRO) classified small and medium companies in one category (those with up to 500 employees).

In Canada, smaller companies have been the primary generators of new employment and the engines of regional growth in recent years. In 1987, it was estimated that small and medium companies with up to 500 employees, generated over 400,000 jobs (APRO, 1991). No jobs were created by larger companies. Nevertheless, small and medium companies are affected the most by an economic recession. Their failure rate tends to be higher than that of larger firms. If they survive, it is because they have produced something of real value to the market (APRO, 1991).

In this study, the sample is divided in two categories, small and large, according to the number of employees. A small company would have up to 500 employees and a large company would have more. The term small is used here for

conventional small and medium sized companies.

3.2.2 Sample

Personal interviews were conducted in order to gain a better understanding of the AMT transfer process. The criteria for selecting the firms and the interviewees are discussed below.

1) Population

Four sources were contacted (Ontario Technology Fund, Carleton University's commercialization Office, National Research Council's Industry Research Assistance Program, and PRECARN Associates Incorporated) in order to obtain names of companies that can be considered in the study. The non-random selection of respondents is believed to be a limitation of the study. However, given that Ontario produces over half of the country's manufacturing goods and has more AMT installations than any other province (Loo, 1987), Ontario companies largely included in this study are believed to be a representative sample of the larger population. Therefore, the results of the study should be generalizable across Ontario and to a large extent across Canada.

The elements of the population are R&D managers, product and process managers, and presidents and individuals that were involved in the technology transfer from the university. The sampling units are adopter manufacturing firms that use and/or sell AMT's in Canada.

2) Sampling frame

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

(i) they have transferred or attempted to transfer an AMT from a Canadian university in the past five years,

(ii) they are located in the vicinities of Ottawa, Toronto, and Montreal (to ensure that the firms would be within reasonable distance), and

(iii) they are Canadian controlled (fully Canadian owned or foreign ownership is less than 51%) parents or subsidiaries. Among other issues, it is believed that establishments with foreign parent companies introduce advanced manufacturing technologies more often than those under Canadian ownership (Betcherman and McMullen, 1986). This approach might affect their AMT transfer decisions from universities.

Intermediary organizations such as research consortia and innovation centres are also included in the study. Intermediaries are believed to mediate between user-companies and universities, facilitating technology transfer to those companies. They also help in obtaining patents, applying for licenses, and in establishing spin-off companies (Gerwin et al., 1990). Therefore, it is worthwhile to investigate their role in the AMT transfer from universities.

3) Sample size

After investigating the suitability of the firms to be

included in the study, a sample of 29 companies was selected. Although most of the companies were from Ontario (a few were from Montreal), the study provides a snapshot of the Canadian context since Ontario has over half of the country's manufacturing installations and produces more manufacturing goods than any other province (Loo, 1987).

A major limitation of the study is the small sample size. This limitation is largely due to the fact that only a small number of Canadian companies adopt technologies developed on university campuses, especially in the AMT area. Three Ontario intermediary organizations were also selected.

3.2.3 Data Collection

The sample was selected and the data collected in the following manner.

- 1) Phone calls were made to potential candidates from targeted companies as well as from intermediary organizations. Candidates were asked if they agreed to participate in the study.

- 2) Appointments were made with 15 candidates from 15 different companies (thirteen from Ontario and two from Montreal), and five representatives from 3 intermediary organizations. Representatives from twelve companies said that they had just started the project with the university and would not be in a position to answer some of the questions. One candidate refused to take part in the study because of the

secrecy involved in his work (although confidentiality of companies' and representatives' names was guaranteed), and another refused due to lack of time.

3) Structured interviews were conducted with company representatives. Objective and subjective data were collected through close and open ended questions. The interview format is listed in Appendix 2. Objective questions required respondents to rate certain incentives, barriers, and success criteria, on a scale of 1 to 5. In addition to incentives for and barriers to transfer, subjective questions concentrated on knowhow transfer, methods of establishing the contact, and intermediary organizations involved in the transfer. Interviewees were encouraged to express any issues that they felt were important, but were not covered within the structure of the interview. They were also asked to answer the subjective questions first. It was felt that they would otherwise be influenced by the content of some of the objective questions.

Interviews with the representatives from intermediary organizations were less structured. This is due to the large difference in types and roles of these organizations. They were asked to discuss their roles as mediators between companies and universities, focusing on a mediation project where appropriate. Some of the open ended questions discussed in Appendix 2 were used in the interviews.

3.2.4 Data Analysis

Both objective and subjective data were analyzed. Subjective analysis was used to provide the rationale behind the objective results, and to provide qualitative backup to the results.

1) Objective analysis

Linear regression, averages and frequency calculations were used to investigate presence or absence of pattern in trend in the data set. However, due to the small sample size, no statistical significance could be confirmed, only trends could be detected.

Linear regression gave an idea about the dependence of companies' incentives for and barriers to transfer on size. Effects of factors other than size on companies' incentives and barriers were also analyzed through the procedure. These factors were R&D percentage of sales spent on AMT projects, and number of full-time R&D members that the company has.

2) Subjective analysis

Subjective responses were examined to determine if they supported statistical results. Subjective data was also used to investigate the other issues covered by the research objectives, such as knowhow transfer, methods of establishing the contact, assessment of readiness of the technology for transfer, success criteria, and intermediary organizations involved.

CHAPTER IV

RESULTS

This research examines the AMT transfer process from universities to industry in Canada. Interviews with representatives from Canadian firms and intermediary organizations were used to achieve this purpose. A detailed description of the sample follows.

Companies

The sample was highly confined to Canadian controlled parents or subsidiaries, due to the effect that foreign ownership might have on AMT transfer decisions. One representative each from fifteen companies were interviewed. The interviewees were: two presidents, four R&D directors, eight product/process or general managers, and one director of university interaction.

Table 4.1 summarizes the profiles of the fifteen firms. As shown, nine companies were small and had less than or equal to 500 employees. The other six companies were large. A complete list of background information about the companies surveyed in the study is presented in Appendix 3.

Projects

For consistency and clarity, the respondents were asked to first talk about successful transfers, if any, and then about unsuccessful ones, if any. Three small companies

TABLE 4.1: COMPANIES' BREAKDOWN BY CHARACTERISTICS

CHARACTERISTIC	RANGE	NUMBER OF COMPANIES	% OF TOTAL
Employees	<=500	9	(59.9%)
	>500	6	(40.0%)
Sales (\$ million)	<=20	5	(33.3%)
	>20 to <=100	2	(13.3%)
	>100	6	(40%)
	Not Available	2	(13.3%)
Company's Age	<=25	12	(80%)
	>25 to <=50	1	(6.7%)
	>50	2	(13.3%)
Ownership <u>Parent</u>	large	3 (all Canadian controlled)	(20%)
	small	6 (all Canadian controlled)	(40%)
<u>Subsidiary</u>	large	3 (one English subsidiary)	(20%)
	small	3 (one Japanese subsidiary)	(20%)

had only unsuccessful transfer attempts. Altogether, fifteen projects (twelve successful and three unsuccessful) were discussed in detail along with brief discussions of eleven unsuccessful projects.

The transfers had taken place at different stages. Of the fifteen major transfer attempts, seven (five successful and two unsuccessful) took place at the development stage. Four successful transfers involved finished products (two hardware and two software). There were three successful

projects where the transfer took place at the research stage, and in a fourth project, the collaboration failed at the research stage. Eleven unsuccessful projects were briefly discussed; eight were development projects and the other three were research projects. Table 4.2 summarizes the stages of development of the technology at the time of transfer (in the fifteen main projects discussed).

TABLE 4.2: STAGE OF DEVELOPMENT OF THE TECHNOLOGY AT THE TIME OF TRANSFER

STAGE OF DEVELOPMENT	NUMBER OF PROJECTS (OUT OF FIFTEEN PROJECTS)	
	SUCCESSFUL	UNSUCCESSFUL
Research	3	1
Development	5	2
Product	4	-

In most of the successful development projects, the university professors had come up with some concepts and showed their applicability by developing prototypes. The companies adopted the concepts and tailored them to their specific needs. Technologies almost always needed modifications and improvements before they could be put to work. Improved awareness of companies' specific needs would certainly help in this work.

The majority of the cases involved manufacturing processes. It seems that this is where the AMT transfer is concentrated. Out of the twelve successful projects

discussed, eleven concerned manufacturing processes while only one involved product and process design technology. The three unsuccessful attempts were also in the manufacturing process area. Of the eleven unsuccessful transfers briefly discussed, ten were manufacturing process projects and one was planning and control project.

Looking at the projects differently, among the fifteen major projects, six software ones were successfully transferred, six hardware ones were successfully transferred, and the three unsuccessful attempts involved hardware. Six technologies were meant for in-house use by the company, six were meant for sale, and three were meant for both purposes. Among the eleven unsuccessful transfers briefly discussed eight were hardware and three were software technologies. Please see Appendix 4 for a more detailed description of the technologies transferred in the fifteen major projects discussed.

In summary, most of the projects discussed, whether successful or unsuccessful, were in the manufacturing process area, and were mostly development projects. Also, the large majority of the unsuccessful projects involved hardware transfers.

Intermediary Organizations

Five representatives from three intermediary organizations were interviewed. Two were from a government

institute, two were from a private research consortium, and the fifth interviewee was from an innovation centre. They discussed their organizations' roles as mediators between companies and universities. Three of them agreed to discuss specific AMT transfers with which they were involved.

4.1 ANALYSIS

The first two sections deal with the relationship between size and incentives for and barriers to AMT transfer from universities. The effect of size is examined through objective and subjective questions.

4.1.1 Size and Incentives

Objective Analysis

Average ratings on incentives were calculated in order to give an idea about the incentives' importance to the different size companies. Average rating was calculated by adding the scores on an item received from all companies in a group (small or large) and dividing the total by the number of companies in that group (nine small or six large).

Table 4.3 summarizes the average scores on incentives. Results suggest that incentives such as accessing expertise available on campus and obtaining a window on science and technology were major incentives for both groups' cooperation with universities. However, some incentives were more important to larger companies than smaller ones and vice

versa. For example, a major reason for large companies' cooperation with universities was getting the technologies at a developed stage, in order to expedite their innovations. A major reason for small companies' cooperation with universities was accessing facilities and instrumentation available on campus.

TABLE 4.3: AVERAGE SCORES ON INCENTIVES

INCENTIVE	AVERAGE (LARGE COMPANIES)	AVERAGE (SMALL COMPANIES)
Access to expertise available on campus	4.00	3.67
Obtain a window on science and technology	3.83	3.33
Access to facilities and instrumentation	2.67	3.44
Lack of in-house R&D staff	2.83	2.33
Solve a particular problem	3.25	3.00
Improve the company's image	2.83	2.44
Uncertainty of costs of internal development	2.08	2.33
Expediting the innovation	4.33	3.11
Demonstration of feasibility of the technology (look and buy)	3.67	2.88
Concentration of In- house R&D on incremental improvements at the expense of radical developments and inventions	2.83	3.00

To examine whether there is an overall difference with regard to incentives for AMT transfer between small and large companies, a sign test (Mendenhall et al., 1986) was undertaken. As Table 4.3 shows, larger companies had higher scores on seven out of ten items. The difference was found to be non significant at even 10% probability level.

If small companies are defined to be those with up to 200 employees, the number of small companies decreases from nine to eight; and the number of large companies increases from six to seven. The average scores on incentives are shown in Table 1 of Appendix 5. No noticeable differences exist between the scores of Table 4.3 and Table 1-App5.

Table 4.4 presents regression results regarding the dependence of companies' incentives on size. Neither one of the relationships is significant. Therefore, results suggest that size does not seem to be a determining factor of companies' incentives for AMT transfer.

R&D Expenditure on AMT Projects and Incentives for Transfer

Besides size, the AMT R&D expenditure (as a percentage of sales) was examined for its influence on incentives for AMT transfer. As Table 4.4 shows, this factor was not related to incentives for AMT transfer. However, no conclusion can be drawn regarding other factors' influence on incentives, which may be investigated in future research.

Subjective Analysis

Respondents were asked about incentives for transferring the specific technology from the university. The respondents spoke of many reasons for cooperating with universities in the specific projects discussed. The most common reasons were: need for expertise in a specific area, need to solve a particular problem, expediting the innovation, and a university's development of a technology (at the product, development or research stage) that the company thought would be beneficial to use.

Other reasons were: attractive price, uniqueness of a technology, need to approach a Canadian university in order to get funding from a governmental institution (e.g., Ontario Technology Fund), and a strategy to publicize collaborative efforts to enhance the company's image. A summary of the incentives which were frequently mentioned in the interviews is presented in Table 4.5.

There were no major differences between small and large companies' incentives for the AMT transfer. Same with large companies, small companies were interested in accessing the expertise and knowledge that universities have. Both groups were also interested in solving particular problems that they had and in enhancing product quality.

In the eleven unsuccessful projects briefly discussed, small and large companies' incentives for AMT transfer were similar to the ones mentioned above. These incentives

TABLE 4.4: DEPENDENCE (R^2) OF INCENTIVES ON SIZE AND ON AMT R&D% OF SALES

INCENTIVE	SIZE	AMT R&D%
Access to expertise available on campus	.02	.01
Obtain a window on science and technology	.00	.17
Access to facilities and instrumentation	.04	.07
Lack of in-house R&D staff	.03	.00
Solve a particular problem	.00	.07
Improve the company's image	.08	.01
Uncertainty of costs of internal development	.09	.02
Expediting the innovation	.11	.00
Need for demonstration of feasibility of the technology (look and buy)	.00	.02
In-house R&D does not concentrate on radical developments and inventions	.05	.06

included: accessing expertise available on campus, solving a particular problem, and improving product quality.

When asked about the importance of universities as a source of AMT as opposed to other sources, twelve respondents indicated that the main reason for their collaboration with universities was also the broad expertise and knowledge possessed by the professors. All large and three small

companies indicated that an important reason for their cooperation with universities was accessing expertise available on campus. High technology equipment that universities had was also an important attraction for five small companies.

Six respondents stressed the importance of company size in the transfer of AMT's from universities. For example, one small company representative discussed that his company approached a Canadian university hoping to get the technology at a developed stage, due to their low R&D capabilities. However, he argued, they ended up with many delays due to the long time the university took to develop the technology.

A representative of a large company felt that they were too advanced for universities to help. However, he mentioned that they sometimes resorted to universities to solve specific problems that were hard to solve internally.

Government labs were seen of less help to small than large companies. While discussing government labs as an alternate source of technology, a small company representative commented that his company tended to approach universities and not government labs in order to avoid the government's "administrative red tape." They tried to avoid government rules and higher administrative costs. The contacts of three small companies argued that government labs were too big and too bureaucratic for them compared to the university labs.

Representatives of four large companies had different

opinions about government labs and universities. They preferred to work with government labs which they considered to be a major source of technical help (consulting). They felt that these labs had broader experience and a greater number of experienced personnel than universities.

In summary, large and small companies were interested in accessing knowledge and expertise available on campus. However, large companies put more emphasis than small companies on incentives like expediting the innovation, and small companies put more emphasis on incentives like accessing advanced equipment available on campus. It was usually hard for smaller companies to support university research. Therefore, they turned to universities when they needed their advice and equipment. Their cooperation with universities was more of a necessity than a luxury. A list of the incentives for transferring AMT's from universities which were frequently mentioned in the interviews, is presented in Table 4.6.

4.1.2 Size and Barriers

Objective Analysis

Table 4.7 summarizes the average scores on barriers. These scores were calculated in order to give an idea about the importance of each of these barriers to the different size companies. Results show that there were some noticeable differences between small and large companies' ratings of the different barriers. For example, time frame difference,

TABLE 4.5: REASONS FOR ADOPTING THE AMT DISCUSSED

INCENTIVE	NUMBER OF LARGE COMPANIES THAT MENTIONED THE SAID INCENTIVE (OUT OF SIX COMPANIES)	NUMBER OF SMALL COMPANIES THAT MENTIONED THE SAID INCENTIVE (OUT OF NINE COMPANIES)	
		SUCCESS (SIX COMPANIES)	NONSUCCESS (THREE COMPANIES)
The contract the company signed with a government institution	1	-	-
The need for enhancing product quality	1	2	1
The need to solve a particular problem	3	1	1
University developed something the company thought it could use	2	2	1
University had the knowledge and expertise	2	2	2
Price seemed to be attractive	-	-	1
Technology was unique and innovative	-	2	-
Expediting the innovation	3	1	-
Enhancing the company's image	1	-	-

university's lack of market awareness, professor's delay in delivery, and university people's pursuance of their own agenda were rated significantly higher by small companies than larger ones. Also, small companies' ratings of most of the barriers were higher than those of large companies.

To examine whether there is an overall difference with regard to barriers for AMT transfer between small and large companies, a sign test was undertaken (large companies had higher scores on three out of sixteen barriers). Unlike the incentives, barriers show significant difference at 5% probability level on an overall basis. This result lends further support to the observation that smaller companies perceive greater hindrances against AMT transfer than their larger counterparts.

Similar to the comparison made with scores on incentives, the barriers scores were recalculated for small companies defined to have up to 200 employees. The average scores are shown in Table 2 of Appendix 5. The difference found is not mention worthy, but, in general, large companies' average scores increased, whereas small companies' scores decreased.

Table 4.8 shows results regarding dependence of companies' barriers on size. The association is examined using linear regression. Results suggest that size could be a determining factor for some barriers that companies face. University peoples' out of touch with the industrial needs, different legal constraints for the company and the

university, and difference in views on intellectual property rights were the barriers that varied significantly with size. It seems that universities were more aware of a certain group's needs (on the basis of the barriers' ratings by small and large companies, it was probably large companies' needs) than the other. Also, results suggest that the intellectual property rights and legal constraints formed more obstacles to one group's cooperation with universities than the other. Again, results should be interpreted with caution due to the small sample size.

One may argue that the responses from companies with successful experience would differ from these with unsuccessful attempts. There is some validity in this argument; a university's lack of awareness of a company's need(s), or a conflict over intellectual property rights might highly affect the outcome of an AMT transfer, resulting in an unsuccessful transfer. To determine the strength of this argument with the present data, average scores on the barriers with significant dependence on size were calculated for the small companies with successful transfers and those with unsuccessful transfers. Results suggest that the projects' success had little influence, if any, on the ratings of these barriers. Different legal constraints and ownership of intellectual property were not significant barriers to transfer neither for small companies with successful transfers nor for those with unsuccessful transfers. Universities' lack

TABLE 4.6: GENERAL INCENTIVES FOR AMT TRANSFER

INCENTIVE	NUMBER OF SMALL COMPANIES THAT MENTIONED THE SAID INCENTIVE (OUT OF NINE COMPANIES)		NUMBER OF LARGE COMPANIES THAT MENTIONED THE SAID INCENTIVE (OUT OF SIX COMPANIES)
	SUCCESS (SIX COMPANIES)	NONSUCCESS (THREE COMPANIES)	SUCCESS (SIX COMPANIES)
Training for companies' staff	-	-	1
Broad Expertise and Knowledge	5	1	6
High tech equipment	3	2	-
Non-industrial research focus	3	-	-
Expediting the innovation	2	-	4
Reasonable costs	2	-	-
Universities' large labs	1	1	-
Contracts with the government that obliges them to work with Canadian universities	-	-	1
Geographical proximity	1	1	-

TABLE 4.7: AVERAGE SCORES ON BARRIERS

BARRIER	AVERAGE (LARGE COMPANIES)	AVERAGE (SMALL COMPANIES)
Time frame difference	1.50	3.11
Different legal constraints	1.67	1.22
Different decision making styles	2.33	2.78
Information dissemination conflict	1.67	1.67
Ownership of intellectual property	1.67	1.44
Need for extra funds and staff to utilize university inventions	2.08	2.67
Lack of communication in the university	1.33	2.11
Lack of communication in the company	1.67	1.44
Lack of communication between the company and the university	2.00	2.33
University lacked the expertise needed to manage the transfer	1.17	2.22
Company's subjective judgement of the technology	1.50	1.78
University's lack of market awareness	1.83	3.33
Prof's delay in delivery	1.5	2.78
Uncertainty related to research results	1.67	2.11
The university people pursued their own agenda	1.67	2.67
High costs	1.75	2.33

of market awareness, on the other hand, was believed to be a major barrier to small companies' cooperation with universities, both in the successful and unsuccessful transfers. A summary of the averages is presented in Table 4.9.

R&D Expenditure on AMT Projects and Barriers to Transfer

The same factor examined with regard to incentives, was also analyzed for barriers. Table 4.8 shows the results of regression. Barriers' association with this factor was not significant. Dependence on size was more significant.

Subjective Analysis

In the discussion of the fifteen major projects, five large companies and three small companies explained that they did not encounter any significant barrier to AMT transfer from universities. A barrier that was mentioned by four small and one large company, is the time frame factor. Time was an important attraction for companies to deal with universities. They expected to expedite their inventions by getting the technology at a developed stage from the university. However, they ended up with delays in getting the technology because, as some representatives believed, universities were too slow in development and concentrated on long term research.

Table 4.10 presents a summary of the barriers discussed. In general, it seems that large companies faced less problems

TABLE 4.8: DEPENDENCE (R') OF BARRIERS ON SIZE AND ON AMT R&D% OF SALES

BARRIER	SIZE	AMT R&D%
Different time frames	.08	.00
Different legal constraints	.30**	.01
Different decision making styles	.00	.02
Information dissemination conflict	.15	.05
Ownership of Intellectual property	.25*	.02
Need for extra funds and staff	.01	.13
Lack of communication in the university	.10	.00
Lack of communication in the company	.16	.01

* significant at 0.1 probability level

** significant at 0.05 probability level

than small companies in their AMT transfers from universities. Different time frames, low communication level between the company and university, different interests and disagreements over disseminating research results were among the most frequently mentioned barriers. Other barriers encountered were: low product quality, high costs, professors' dishonesty, lack of market awareness, and university's bureaucracy.

TABLE 4.8: DEPENDENCE (R²) OF BARRIERS ON SIZE AND ON AMT R&D% OF SALES-Contd

BARRIER	SIZE	AMT R&D%
Lack of communication between the company and the university	.02	.01
University lacked the expertise needed to manage the transfer process	.11	.01
Subjective judgement of the technology by the company's staff	.02	.02
University's lack of market awareness	.32**	.00
Professor was late in delivery	.14	.01
Uncertainty related to research results	.05	.06
The university people pursued their own agenda	.12	.02
High costs	.03	.03

** significant at 0.05 probability level

Without being asked to, six respondents discussed the influence of company size on barriers to AMT transfer. For example, in an unsuccessful project with a small company, the company was not happy with the quality of the "parts" obtained from the university. They had to have them reworked, paying five times more than they thought they would have to pay originally. The respondent argued that small companies cannot

TABLE 4.9: SMALL COMPANIES' AVERAGE SCORES ON BARRIERS WITH SIGNIFICANT DEPENDENCE ON SIZE

BARRIER	AVG SMALL-UNSUCCESSFUL	AVG SMALL-SUCCESSFUL
Different legal constraints	1.00	1.33
Ownership of intellectual property	1.00	1.66
University's lack of market awareness	4.00	3.00

usually afford such an expense.

A representative of a small company felt that the academic setup is not conducive to business. He argued that academics like bigger projects than what small companies can afford. He recalled a case where they approached a Canadian university with an AMT project idea. The university showed interest in the beginning, but refused to continue the relationship due to the smallness of the project. That was the first time the company had approached a university and the respondent believed they would never approach universities again.

Another small company representative said that a major inhibitor to transfer and a reason for ending up with an unsuccessful project was a professor's dishonesty. Half a year after the set date, the professor came up with something that was half cooked and almost useless. He did not tell the company what he was doing and did not submit a single report.

This same representative narrated a story he heard from a colleague in the same industry, about a professor who was funded by a company to develop a technology for them. After the technology was developed, the professor went as far as refusing to supply the company with the final results because, as he claimed, "the development part was mentioned in the contract but not the time of delivery!"

The barriers in the other eleven unsuccessful projects were similar to the ones listed above. However, they were mentioned more frequently in the context of these unsuccessful transfers, and were more often faced by smaller companies.

Clearly, large companies seem to have faced less problems than small companies in their relationships with the universities. Five of the six large companies interviewed did not face significant barriers to their AMT transfers from universities. But only three of the nine small companies could claim the same.

4.1.3 Some qualitative results

In order to gain a better understanding of the current AMT transfer process, the participants were asked for their opinions on the following issues: methods of establishing contact, intermediary organizations involved, methods of knowledge transfer, the success criteria used by their companies to evaluate the projects, assessment of readiness of the technology for transfer, and ways of improving the AMT

TABLE 4.10: BARRIERS TO AMT TRANSFER

BARRIER	NUMBER OF LARGE COMPANIES THAT MENTIONED THE SAID BARRIER (OUT OF SIX COMPANIES)	NUMBER OF SMALL COMPANIES THAT MENTIONED THE SAID BARRIER (OUT OF NINE COMPANIES)	
	SUCCESS (SIX COMPANIES)	SUCCESS (SIX COMPANIES)	NONSUCCESS (THREE COMPANIES)
Time frame	1	2	2
Different interests	-	1	2
High costs	-	1	1
Disseminating research results	2	1	-
University's bureaucracy	-	1	-
Low communication level between the company and the university	2	1	1
Low product quality	1	-	1
Professor's dishonesty	-	-	1
No uptodate equipment and machines at the university	-	-	1
University's lack of market awareness	-	1	1

transfer process from universities. These issues were discussed by Gerwin et al. (1990). To enable the comparison, they will be discussed in the following sections.

1) Methods of Establishing Contact

Results indicate that the contacts were established through four major channels. The company was either approached by the professor or the university, or was the one who approached them. No intermediary organization was used in establishing the contact. Only information on the potential source of technology was supplied by two intermediary organizations to their member companies. Table 4.11 shows the different channels that were used to establish the contacts in the fifteen major projects.

In seven projects, the contacts were established on the basis of on-going relationships with the professors or familiarity with the professors' expertise in certain areas. Such familiarity can come through peers, publications, graduate students, and other sources. One small company representative reported that they, as a spin-off company from the university they approached, always had a strong relationship with it because of their roots. It seemed natural for them to approach the university.

In the eleven other unsuccessful projects discussed, the company approached the professor in six projects, and in two projects, the company approached the university. The company was approached by the professor in two projects and by the university in one project. The frequent use of the proactive approach by the companies investigated gives the indication that the Canadian manufacturing company is trying to tap the

university for technology, and become an active partner in this relationship.

TABLE 4.11: METHODS OF ESTABLISHING CONTACT

Method	Number of companies that mentioned the method	% of Total
The company approached the professor	9	.60
The company approached the university ¹	4	.27
The professor approached the company	1	.07
The university approached the company	1	.07
Total	15	100%

2) Type and Role of Intermediary Organizations Involved

Gerwin et al. viewed intermediary organizations as a new development that provides a wide variety of services in the transfer of AMT. These services include matchmaking between professors and companies, obtaining patents, negotiating licenses, developing business plans, getting funds for continued development, forming consortia, and creating spin-offs. Examples of such intermediaries are: Centres of

¹ "The university" refers to any representative at the university other than the professor (e.g., industry liaison officer, a specific university department representative, etc.).

Excellence (e.g., Manufacturing Resource Corporation of Ontario (MRCO)), private consortiums (e.g., Canadian Semiconductor Design Association, PRECARN Associates Inc.), and innovation centres (e.g., Innovation Centre of Waterloo).

An important finding of this study is that only two companies used intermediary organizations for their projects with the universities, in spite of the fact that many of these companies were members of intermediary organizations. Assistance supplied to the two member companies was in the form of advice on the source of technology (the Canadian university).

Some unexpected remarks were made by some companies' contact persons when they were asked about the role intermediary organizations played in the transfer process. Two respondents mentioned that they did not have to resort to intermediary organizations in the projects discussed. Two other respondents discussed that it was useless to use intermediary organizations such as a research consortium in the transfer process, as this would have forced them to deal with competitors which would have made things more complicated! However, three respondents believed that, in the mean time, intermediaries' role should be further supported in order to build a strong relationship between companies and universities in Canada.

Other organizations involved in the transfer process were suppliers of funding. These were basically government

institutions such as the Ontario Technology Fund (OTF), Natural Sciences and Engineering Research Council (NSERC), and Industry Science and Technology Canada (ISTC).

In summary, it seems that companies avoid use of intermediary organizations. They prefer to have a one to one relationship with the university. More will be said about intermediary organizations when discussing the interviews conducted with five representatives from three intermediary organizations.

3) Methods of Knowledge Transfer for Proper Use of Technology

Several methods were used to transfer knowhow to the companies. The most common methods were written reports and face to face conversations. Graduate students and/or professors used to visit the companies labs to understand the basic problems they were trying to solve. They used to work on the solutions together with the company staff. Table 4.12 summarizes the most common methods used in the fifteen main projects discussed to transfer the knowhow.

In most of the successful projects, more than one method was used to transfer the knowledge to the company. In two unsuccessful projects, no knowledge was transferred. One project failed in the preliminary stages because of the university's refusal to work on a small project with a small company. The other project failed in the development stage because of lack of communication between the company and the

professor. In the third unsuccessful project, a prototype was developed and the knowledge for its use was transferred. However, the company did not think the prototype met the technical specifications. Knowhow was not transferred in most of the eleven unsuccessful projects. In few cases, face to face conversations and written reports were used to transfer the knowledge.

Knowledge transfer depends not only on the source but also on the receiver of the information. Professors and students will be able to transmit their knowledge effectively only if the receiving end has the necessary skills to understand the technology. This factor, as a large company's representative commented, highly affects the success of the technology transfer.

4) Success Criteria

This study considers a transfer to be a success if a transfer of location (of a product), responsibility, or knowledge was achieved or adequate progress was made. However, if the transferred technology was not the one agreed on initially, the transfer was not considered successful. To the extent possible, concentration was made on identifiable inventions, whether hardware or software, that were partially or completely developed as opposed to research results.

Five major criteria were listed in the questionnaire for rating: impact on profit, impact on sales, continuation of relationship with the university, meeting technical

TABLE 4.12: METHODS OF KNOWHOW TRANSFER

METHOD	FREQUENCY MENTIONED
Written reports	8
Face to face conversations	10
Graduate hiring	3
Manuals	1
Professor hiring	2

specifications, and utilization of the technology by using it in-house or by selling it. Respondents were also encouraged to mention other criteria that they used to judge the project's success.

Respondents had many definitions of success. For some, a successful technology transfer was a transfer that resulted in a successful commercialization of a product. Others defined success of TT as success in meeting technical specifications. The highest rated success criterion was technology utilization. Another highly rated criterion was meeting technical specifications. Table 4.13 shows the criteria's average ratings.

The companies put more emphasis on technology utilization and technical specifications than impacts on profit and sales. Perhaps this emphasis on technical success rather than commercial success is to be expected as most of the transferred technologies were related to manufacturing processes. However, those respondents who were talking product technology did not seem to emphasize commercial

TABLE 4.13: SUCCESS CRITERIA'S AVERAGE RATINGS

SUCCESS CRITERIA	AVERAGE RATING (OUT OF FIVE)
Impact on profit	2.73
Impact on sales	2.49
Continuation of relationship with the university	2.80
Meeting technical specifications	3.80
Utilization of the technology	3.93

success. Another criterion that was mentioned by two respondents was the transfer's effect on the company's relative position in the industry. For example, if a technology gives them a competitive edge in the industry, they would consider the TT successful.

5) Assessment of Readiness of the Technology for Transfer

Assessment of readiness of a technology for transfer was mostly based on personal judgement of a professor or company representative(s). No specific criterion was used for this purpose. However, companies usually had certain technical specifications that they expected universities to meet before transferring the technologies. These specifications were usually laid out in the research contracts.

6) Methods of Improving the Transfer Process

Respondents were asked for their suggestions for improving the AMT transfer process. Improved communication

between companies and universities was recommended by twelve interviewees for enhancing AMT transfers in Canada. Increasing university-industry exchange programs was one method proposed for improving the communication. These programs were believed to increase the possibility of matching the right professor with the right company.

Nine respondents said that universities and companies should become more "serious" about the relationship. They believed that universities should understand the business requirements of a company (e.g., quick delivery and high reliability of the invention developed) that give it a competitive edge. Companies, on the other hand, should familiarize universities with what they need. They should try to work with them on the development from early stages on. Three respondents also believed that universities should not develop inventions or create new applications without interfacing with the industry.

Two respondents liked to work with the "younger" professors, because they better supported the university-industry relationship. The respondents claimed that older professors seemed to be far from the industry because they feared the relationship would inhibit their scientific spirit.

Two respondents suggested that technology should be further developed at the university than it is now done. Two others believed that the development should be done at the industry's premises. Universities, they argued, should

concentrate on coming up with new technologies and on doing research.

Research contracts were seen by some respondents to be very vague. They felt that the financial aspects were usually clarified but ambiguity remained in definition of deliverables⁴. They stressed that specific objectives should be set in research contracts in the form of specific expectations of companies and universities. The difficulty of designing unambiguous research contracts is intensified when two TT projects have conceptual overlaps. Sponsor of each project wants to claim not only the research, but also the fruits of research.

Many respondents believed that the Canadian government could do much about the university-industry relationship. They felt that the government's programs that put industry and universities together were helpful, but should be better supported and enhanced. Other respondents were despaired about the government's role and were convinced that, in the long run, industry will have to develop closer relationships with universities without relying on government's support.

A representative of a Canadian multinational company with subsidiaries in six European countries argued that the relationship between universities and companies was better in

⁴In some exploratory research, it may be impossible to define deliverables.

those countries. In his opinion, the European Companies obtained considerable tax incentives to support joint research. In Canada, industrial funding was less, and many small- and medium- size companies could not afford to support university research. If the situation remained the same, he argued, Canada would not be able to compete with the rest of the world, and would even lose its current economic status. The suggestions are summarized in Table 4.14.

TABLE 4.14: SUGGESTIONS FOR IMPROVING THE AMT TRANSFER PROCESS FROM UNIVERSITIES

SUGGESTION	FREQUENCY MENTIONED
Improve communication between companies and universities	12
Enhance and support the Canadian government's university-industry programs	3
Familiarize universities with the market need	3
Better define research contracts	3
Professors should deliver in a more timely fashion	2
Develop technology further at the universities	2
Companies should work with the younger professors	2
Develop the technology at the industrial site and let universities concentrate on breakthroughs	2
Establish long term relationships	1
Seek more funding from government to support joint-projects	1
Overcome the "not invented here syndrome"	1
Balance the rights on intellectual property	1

4.2 INTERMEDIARY ORGANIZATIONS

The following summarizes the interviews with the five representatives from three intermediary organizations. These interviews centred around the role the intermediary organizations play as mediators between universities and industry. The semi-structured interviews covered a government institute, a research consortium, and an innovation centre. Questions marked with an asterisk in Appendix 2 were used in some interviews. They covered: methods of establishing the contact, success criteria, knowhow transfer, incentives for transfer, and barriers to transfer.

4.2.1 Government Institute

Two representatives from a government research institute were interviewed. The institute was administering a research assistance program for small enterprises. This program assisted manufacturing, resource, construction and service industries. It used two forms of assistance: 1) technical help, and 2) contribution towards employee salaries. Eighty percent of the salaries were paid for by the program.

Regarding activities with universities, more than 40% of the program's money was allocated for university-industry programs. Funding was usually supplied over a three to five year period, and was given to:

- 1) Universities that dealt with their agent companies (those who approached the program for help),

- 2) Companies that had sub-contracts with universities, and
- 3) Companies that hired students (e.g., co-op students), and professors.

Only 15% of the program's budget went to large companies. The program helped large companies in the preliminary, technical feasibility, and high risk stages. The respondents explained that the program's concentration was on small- and medium-size firms because the program's budget was too small to have an impact on large organizations. In addition, the need for financial assistance was usually large in small companies.

Regarding intellectual property rights between 1962 and 1989, companies used to own and control the intellectual property rights. Since 1989 the government institute owns the intellectual property rights while giving the company access to the technology. In university-industry mediation projects, two contracts were usually signed: one between the government institute and the company to get funding, and one between the company and the university. If a university wanted to give a company exclusive rights over a technology, it was usually negotiated with government representatives.

Until the late eighties, the institute approached the professors directly. The practice was changed to approaching the industrial liaison offices instead. Respondents believed this method to be more effective but more time consuming.

A problem that the program encountered was with the

support of the manufacturing companies, because of the high cost of the non-labor portion. In manufacturing firms, employee salaries and wages typically account for only up to 30% of variable cost. Therefore, the program's support was usually no more than 80% of that figure. Many manufacturing firms did not benefit from this program as much as their counterparts in non-manufacturing sectors.

The program supported several projects of AMT transfer from universities, but only a few were successful. The interviewees' advise the manufacturing companies and the universities to build AMT transfer relationships-gradually-by starting with smaller projects.

4.2.2 Innovation Centre

Innovation centres customarily provide space for startup firms to locate. They focus on research and development services and usually avoid manufacturing. They are frequently situated near major university campuses so that the businesses that locate in them can take advantage of university resources (Powers et al., 1988).

An R&D director in a ten year old innovation centre was interviewed. The approximate number of employees at the centre was fifteen, six of which were full-time R&D staff. The expenditure on AMT projects was about ten percent of the R&D budget. The centre was involved in private consulting and mediation between some Canadian companies and universities.

The director discussed an AMT transfer from a Canadian university to a Canadian manufacturing company in which the centre acted as an intermediary. The technology was in the product design category. The R&D department, on behalf of the company and innovation centre, approached the university. They had an arrangement to work with this university on joint projects.

The commercial potential of the technology was estimated on the bases of projected sales of an item featuring it, and of the impact generated on profit. The innovation centre managed to take rights to the prototype developed. However, there was a pressure on them to refine the technology and develop it fully.

The respondent believed that universities offered a wealth of technical and human resources that industry did not have. However, he believed that the university-industry co-operation was not getting enough support in Canada, especially in the AMT area. He suggested improvements in universities' and innovation centres' market awareness, increase in funding for companies to utilize university research, and improvement in communication between universities, intermediary organizations and industry.

4.2.3 Research Consortium

Two respondents from a seven year old research consortium were interviewed. The consortium used to have six member

companies in 1989 but two companies went out of business. The remaining four are small companies in the integrated circuits industry.

The consortium supplied its members with information on research in their areas. Each member was able to apply the technical expertise of the other members to its own products, and obtain performance and cost advantage.

The consortium has had involvement in three transfers from Canadian universities, and many transfers from other sources. R&D activities of its member companies expanded in 1988, as it was then that they gained the Ontario Technology Fund support to enhance the integrated circuit technology base in Ontario.

One respondent, who was also the president of a nine-month old microelectronics consortium, discussed a case involving a Canadian university and two member companies. The companies spent a lot of money to enable the university create a prototype; but the invention could not be used as there was no market for it and creating the market was expensive.

The other respondent discussed another transfer from the same university to two other member companies. The consortium came to know that a professor was working on a project that might be of interest to the companies. They informed the companies and arranged for them to deal with the professor directly. A prototype was built at the university, further

developed by the companies, and then used. Knowhow for it is use was transferred through reports and face to face conversations.

Both respondents believed that applicability of a technology is the major determinant of an AMT transfer success. In spite of the fact that universities constituted a major source of expertise and knowledge, they argued, their insufficient knowledge of industrial needs was a major inhibitor to AMT transfer.

4.3 DISCUSSION

4.3.1 Summary and Conclusions

This study investigated the Canadian manufacturing industry's perspective of the AMT transfer process from Canadian universities. Amongst other issues, the relationship between company size and its incentives for and barriers to transfer were investigated.

Data were collected from nine small (≤ 500 employees) and six large companies (> 500 employees). In order to gain a better understanding of the AMT transfer process, respondents were asked to concentrate on successful AMT transfers from Canadian universities. In total, twelve successful and three unsuccessful projects were discussed in detail. Also, eleven unsuccessful projects were briefly discussed.

Out of the four groups of advanced manufacturing technologies, manufacturing process was the area where most of the transfers took place. Twenty four of the twenty six projects involved manufacturing processes. Cooperation in other areas such as product and process design and in integrative activities such as computer integrated manufacturing does not seem to be receiving enough support.

Fifteen projects were still at the development stage at the time of transfer. In fact, very few technologies are being fully developed on university campuses. Refinements are usually needed before the technology can be put to work.

Incentives for and barriers to AMT transfer were

separately regressed on size to test their dependence. Objective responses by interviewees suggest that size does not seem to be a determining factor of companies' incentives for AMT transfer. However, size seems to be a determining factor of some barriers that companies face in their AMT transfers. University's lack of market awareness, different legal constraints for the company and the university, and difference in views on intellectual property rights varied significantly with size. Subjective responses suggest that incentives and barriers are both influenced by company size, however, the relationship between size and barriers seems to be stronger than that between size and incentives.

The influence of R&D expenditure in AMT (as a percentage of sales) on incentives and barriers was also investigated. No statistical significance was found.

Other issues investigated were: methods of establishing the contact, role of intermediary organizations, methods of knowledge transfer, assessment of readiness of the technology for transfer, success criteria used by companies to judge a project's success, and suggestions for improving the transfer. The results are summarized below.

Four channels were used to establish contacts. A company was either approached by a professor or university (reactive mode), or was the one who approached a university or professor (proactive mode). The latter approach was more common in the sample. One interpretation of this is that the Canadian

manufacturing sector is aware of the benefits of TT from the university community.

In the large majority of the projects, no intermediary organization was involved. This is despite the fact that many companies were members of intermediary organizations such as research consortiums and Centres of Excellence. Perhaps companies prefer to deal directly with universities, or are not fully aware of intermediary organizations services.

In most cases, knowhow for proper use of technology was transferred through face to face conversations and written reports. Perhaps these are the most effective methods for this purpose. More importantly, most of the unsuccessful projects are characterised by a lack of knowhow transfer.

Respondents emphasized technical success as opposed to commercial success. The fact that most of the projects were regarding manufacturing processes might have affected this result. Nonetheless, respondents who discussed product technology seemed to be more concerned about technical rather than commercial success.

Very few companies used specific criteria to estimate a technology's readiness for transfer. Meeting technical specifications was used as an evaluation criterion by some companies.

The respondents had many suggestions for improving AMT transfers from Canadian universities such as:

- improving the communication between the industry and

universities,

- enhancing the government's university-industry programs,
- familiarizing universities with market needs, and
- better defining research contracts.

Universities were seen as an important source of advanced manufacturing technologies by many respondents. However, they believed that universities were not and would never become competitors to local industry. They argued that universities should be expected to give support to local industry while maintaining their role as disseminators of information. All respondents agreed that there is still a lot to be done by the industry, universities, and government to improve and nourish this relationship.

4.3.2 Comparison with the University Perspective

One of the themes of this study has been to compare the views of the Canadian manufacturing industry to those of the Canadian universities. The views of Canadian universities were described by Gerwin et al. (1990) and were summarized in the literature review of this thesis. A comparison between the similar issues investigated in the two studies follows.

Technology Transferred

Sixteen professors were interviewed by Gerwin et al. They discussed one project each. Ten projects involved manufacturing process technology, four involved technologies for product or process design, and two related to

manufacturing planning and control technologies.

In the current study, twenty four of the twenty six projects were related to manufacturing processes, one was a product and process design project, and the last one was a planning and control project. The comparison suggests that indeed the greatest interest in AMT is in the manufacturing processes area.

Methods of Establishing the Contact

In ten of the sixteen projects discussed in the Gerwin et al. study, the companies approached the professors with their needs. Six professors had reported that the transfers were initiated because of their long term relationships with some engineers of the user firms.

The results of this study agree with the findings of Gerwin et al. The companies initiated the contact in twenty one of the twenty six projects. They were more proactive than the universities or the professors in this respect. Six contacts were established on the basis of a long term relationship between a company and a professor. It seems certain that the companies are more aware of the benefits of cooperation than are the universities.

Knowhow Transfer

The professors reported that written documents were the most preferred vehicle for transferring the knowledge on proper use of inventions. In most instances, face to face conversations had accompanied the written reports.

Written reports and face to face dialogues were also the most popular means for transferring the knowledge, according to the recipients of technologies. Face to face discussions seem to have two advantages. It is not only effective in knowhow transfer, but can also lead to long term relationships between industrial engineers and professors, which is so necessary for improving the AMT transfer process.

Readiness For Transfer

In the sixteen projects examined in the Gerwin et al. study, technology evaluation was mostly undertaken through estimating the technology's readiness for transfer. In eight projects, the professors evaluated their technologies against technical specifications laid out in the research contracts. Another eight evaluations of readiness for transfer were based on unilateral decisions by the professors or companies. Unilateral decisions taken by companies to transfer the technologies were believed to be a result of professors' failure to meet the deadlines of their projects.

According to the industrial representatives, they used no specific criteria for estimating technologies' readiness for transfer. It was mostly based on personal judgement. In some cases meeting technical specifications was used as a criterion for this purpose. Therefore, the only evaluation criterion used by professors and company representatives was meeting technical specifications.

Intermediary Organizations

Same with industry representatives interviewed in the current study, the professors in the Gerwin et al. study rarely used intermediary organizations for transferring technology. Despite the variety of services that intermediary organizations offer, it is surprising that their services would be used so rarely for TT. It appears that there is a great deal of uncertainty regarding the effectiveness of these organizations as technology brokers.

Barriers to Transfer

There seems to be a great deal of agreement between the university and industry people regarding the barriers to AMT transfer. For instance, many industrial representatives pointed, and many professors and liaison officers agreed, that the universities were often late in delivery. Similarly, many university staff pointed out that the not invented here syndrome in many companies was a major barrier to their relationship with the industry; the industrial representatives agreed.

The companies and the universities accused each other of failure in some cases. For example, the universities complained that the companies had little knowledge of university services. Some companies (mostly small) on the other hand, thought that the universities were unaware of their needs. It is obvious that a great deal of work needs to be done to increase the awareness of the two solitudes: the

PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
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PRECISIONSM RESOLUTION TARGETS

university and the small firms.

Incentives for Transfer (Benefits)

Each group spoke of their own benefits. For example, universities benefited from "reverse technology transfer". In many instances, they gained technical knowledge as a result of the projects with the industry. These projects also enabled them to buy advanced equipment for research, which they could not have afforded otherwise. Other incentives for transfer included financial earnings and support for students.

Amongst companies' incentives for transfer were accessing expertise and advanced equipment available on campus, obtaining a window on science and technology, expediting the innovation, improving product quality and reducing its cost, and improving the company's image. Improved knowledge and financial gains were major incentives for both groups to cooperate.

Success Criteria

Professors viewed success of a TT project from a technical perspective. Neither financial rewards nor the promise of a long-term relationship with industrial partners were significant to them. They used no systematic procedure to measure success. Liaison officers at the universities viewed success in terms of royalties and the amount of sponsored research funds that universities obtained. Some of them thought if good relationships between professors and companies resulted, and universities reputation was enhanced,

projects would be considered successful.

Like the professors, the company representatives viewed success from a technical perspective. While some emphasized commercial success, most stressed technical success as a valid criterion. They seemed less interested in establishing long term relationships with the professors.

Universities and companies shared many ideas about AMT transfer. Yet, there is a lack of actions towards improving this transfer. Actions which are believed to enhance AMT transfer, or can be inferred to have such potential are listed below. Some of them are to be taken by the governments, some by the industries, some by the universities, and some by the future researchers.

4.3.3 Recommendations

In Canada, very few university to industry AMT transfers have taken place in the past five years. The following changes would help rectify the relationship.

Recommendations to Government

- A fact that was stressed by a representative of a small multinational company was that incentives which support university-industry cooperation are much less in Canada than in other countries such as the U.S and some European countries. Therefore, the Canadian government could develop policies targeted toward better cooperation.
- Canadian universities need to know more about the industrial

needs, particularly, those of smaller companies; and many of these companies, need to be aware about the universities' modern services. However, universities should sometimes be fed with innovative ideas and informed about market needs. Companies, on the other hand, should be informed about universities services. Educational programs and seminars in these regards are sure to make a difference. The governments, therefore, can support undertakings such as NRC's colloquium on collaborative research programs in Canada.

- In order to take the research to the application stage, the government should support continued development of technologies-financially and technically-at the university campus and at the company's premises.

- Most of the AMT transfers occurring in Canada are in the area of manufacturing processes. The governments should target funds and campaigns to encourage projects in areas such as product and process design as well.

Recommendations to Universities and Industry

- Canadian manufacturers must establish more transfer links with universities. They should, however, become more selective about the technologies they try to transfer. This would reduce the risk of ending up with a noncommercial technology. But, they can be profitably selective only if there are appropriate and practical selection criteria. Researchers, therefore, must address this issue.

- Too many projects fail due to improperly defined research contracts. Universities and industry should negotiate better and learn to write workable research contracts that are acceptable to both groups. Perhaps there is a room for specialist mediators to guide the negotiations on behalf of the government.

- Universities and manufacturers should work toward more long-term relationships in order to facilitate AMT transfer. Addressing this issue, Gerwin et al. (1990) suggested that professors should be granted leaves of absence for spending time with firms and full-time employees of companies should be allowed to study or teach at a university. Liaison offices can encourage long-term relationships through a variety of campaigns.

- Currently, most of the contacts are initiated by companies. The recommendation of Gerwin et al. (1990), therefore, can be echoed to suggest that the university communities become more proactive.

- Universities must become prompt in delivery. This is a call for attitudinal change among the professors and other related university staff. A research contract with a private firm must be viewed as a business contract. On the other hand, the industrial receivers must accept that the university professors ought not be under their beck and call. The purity of research has to prevail.

Recommendations for Future Research

- Most of the AMT transfers taking place in Ontario involve manufacturing processes. Future research should investigate the reasons for the rarity of product and process design, and planning and control transfers, that are essential for keeping Canada's competitive ground.
- Future research should examine the reasons for the lack of utilization of the intermediary organizations, even by the member companies. Involvement of these organizations could reduce the communication gap that is now a significant barrier.
- No specific criteria were used to estimate the technologies' readiness for transfer, and in many instances it was left to unilateral decisions by the company or professor. The lack of well researched criteria will continue to cause differences in opinions between universities and companies with regards to readiness of the technology for transfer. Researchers should address this concern.
- In the context of the above, it is also noteworthy that poorly defined research contracts formed significant hindrances to AMT transfer. Therefore, researchers should investigate quality and nature of research contracts, and the processes that produce contracts between the companies and universities.
- Future research should also examine AMT transfer policies of non-Canadian companies located in Canada, and compare them

with those of Canadian companies. This investigation should cover AMT transfers from Canadian and non-Canadian universities. As a result of this research, Canadian companies and universities can benefit from the AMT transfer experiences of foreign companies and universities.

- A different perspective on incentives and barriers may be learned by investigating Canadian manufacturing companies that use or sell AMT's but do not transfer them from universities (mainly Canadian universities). Such a study will help discover the reasons for their resentment to this relationship.

- There will always be pockets of criticism against universities' focusing their research resources for commercial gains; there will also be some pressure for the universities to provide visible advantages to the society and the taxpayers. This conflict was in the background in most of the interviews. Research and debate should be encouraged to resolve the issues to fit the standard of Canadians.

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Appendix 1

THE ADVANCED MANUFACTURING TECHNOLOGIES

Advanced Manufacturing Technologies are a family of techniques used in product design, the production process, manufacturing planning and control, and in integrative activities. They can be readily adapted to a variety of uses through computer programming, and perform a significant part of their functions without direct human intervention. They may consist of mainly hardware, mainly software, or some combination. The scope of this definition, here, is restricted to discrete parts manufacturing.

1. PRODUCT AND PROCESS DESIGN

1.1 Computer-Aided Design (CAD)

Helps create or modify engineering designs and store geometry of the part in a computerized data base.

1.2 Computer-Aided Engineering (CAE)

Use of simulation and other techniques to analyze the properties of a design such as the stress in a mechanical part.

1.3 Computer-Aided Process Planning (CAPP)

Helps in planning the sequence of production operations a part will go through on the shop floor.

1.4 Group Technology (GT)

Taking advantage of similarities in design or manufacturing requirements to group parts into families with similar attributes.

1.5 Cellular Manufacturing

Rearrangement of production equipment on the shop floor into groups, each of which is responsible for one or more part families.

2. PLANNING AND CONTROL

2.1 Material Requirement Planning (MRP)

A computer based information system for production scheduling, ordering and inventory control of all items (materials, components, sub-assemblies) that go into a finished product .

2.2 Manufacturing Resource Planning (MRP II)

An expanded version of MRP which incorporates planning for needed financial and marketing resources.

2.3 Computerized Preventive Maintenance (CPM)

Aids in planning, scheduling, record keeping and report preparation for routine maintenance aimed at reducing equipment failure.

2.4 Expert Systems

A computer program which applies rules of thumb called heuristics to find satisfactory solutions to a particular complex problem; often the rules are obtained from an individual who is an excellent solver of the problem.

3. MANUFACTURING PROCESS

3.1 Processing Equipment-Stand Alone

3.1.1 Numerical Control (NC):

A general purpose machine tool or machining centre which uses instructions coded on a tape to control its operations.

3.1.2 Computer Numerical Control (CNC):

The machine's operation is controlled by a program in a mini or micro-computer attached to the machine.

3.1.3 Programmable Robot:

A multi-functional manipulator which moves a part, tool, or specialized device through variable motions to perform a variety of tasks such as assembly, material handling, painting or inspection.

3.1.4 Machine Vision and Sensing:

Computerized system used to inspect, recognize, gauge, guide, or control parts based on the interpretation of visual or tactile information from the external environment.

3.1.5 Materials Working Laser:

Laser technology used for welding, cutting, treating, scribing and marking.

3.2 Processing Equipment-Systems

3.2.1 Direct Numerical Control (DNC):

Two or more machines without automated material handling controlled by computers or programmable controllers.

3.2.2 Flexible Manufacturing System or Cell (FMS or FMC):

Two or more machines with automated material handling capabilities controlled by computers or programmable controllers; an FMS versus an FMC usually has more machines, more sophisticated components, and allows multiple paths for the parts.

3.2.3 Flexible Assembly System (FAS) or Cell (FAC):

Roughly analogous to an FMS or FMC, except that the machines, which may be robots, put parts together by welding, fastening or inserting.

3.3 Process Control

3.3.1 Parts Programming and Machine Intelligence:

Generation of the coded instructions used to operate a machine, robot or other device. Machine intelligence occurs when the device becomes capable of applying knowledge to respond to various environmental situations.

3.3.2 Computer Process Monitoring (CPM):

Use of a computer for data acquisition about the current state of a manufacturing process.

3.3.3 Computer Process Control (CPC):

The manufacturing process is monitored and controlled by a computer.

3.3.4 Programmable Controllers (PC):

An electronic process control device with programmable memory which puts the steps taken in a particular logical sequence and collects information.

3.3.5 Computer Aided Inspection (CAI):

Helps check the conformance to specifications of parts

typically using an automated programmable device called a coordinate measuring machine, or robots equipped with sensors.

3.4 Automated Material Handling

3.4.1 Automated Storage and Retrieval System (AS/RS):

A computer controlled stocking system in which parts are stored on racks, and received and retrieved using computerized carts, lift trucks, robots, cranes and/or similar devices.

3.4.2 Automated Guided Vehicle System (AGVS):

Unmanned transportation of materials in the factory using vehicles equipped with automatic guidance devices programmed to follow certain paths.

4. INTEGRATION

4.1 Local Area Networks

Telecommunications linkages for exchanging information between different points on the factory floor or within design and engineering departments.

4.2 Inter-Company Network

Telecommunications linkages for exchanging information between the factory, subcontractors, suppliers and/or customers.

4.3 CAD/CAM Integration

Design information is used to automatically generate parts programs which are electronically downloaded to control a machine for production of a part.

4.4 Other Integration

(e.g: CAD/MRP, CAPP/MRP, MRP/ASRS, etc.).

4.5 Computer Integrated Manufacturing (CIM)

Bringing together the individual advanced manufacturing technologies used in product and process design, manufacturing planning and control and the production process under unified computer control using information technology.

Appendix 2

INTERVIEW FORMAT

Interview Guidelines

To be mentioned:

1. Purpose of the interview.
2. Confidentiality.
3. Availability of copy of final report (if desired).
4. Ask for a copy of any documentation of the kinds of projects worked on in conjunction with universities.

Preparation

1. Have the respondent understand AMT definition used in the study by looking over the list of technologies in Appendix 1.
2. In this study, the concern is with AMT transfer from universities to manufacturing firms.
 - a change in location or responsibility for continued development or commercialization (may arise from firms being found or finding the inventor).
 - a transfer of knowledge to facilitate continued development or commercialization.
3. Consider only technical inventions
 - some identifiable invention (hardware/software) which exists partially or completely should preferably exist as opposed to research results.

Questions

Open-Ended

Think of a successful example of AMT transfer with which you have been involved. "Successful" means a transfer in location, responsibility or knowledge was achieved (or adequate progress was made).'

- *1. What is the label and name of the technology? Please describe it including its current uses.
2. For the specific project discussed, why did you decide to adopt the technology from the university, i.e., what was special about the technology and on what bases did you evaluate the technology? (e.g. pricing, usability, delivery).

'Questions with an asterisk were asked to intermediary organizations' representatives.

3. What do universities offer that you do not have and others (e.g. government laboratories) cannot offer? (factors may lie in the technology, the professor, the university, your firm, an intermediary organization or the wider environment)
- *4. At what stage of development (research, development, or product) was the technology transferred? Why?
- *5. How was the contact between you and the university established? why did you choose the mentioned approach(es)?
- *6. Explain the type and role of organizations/intermediaries involved, if any (e.g., Research Consortium, Spin-Off company, Research Centre).
- *7. How was the knowhow for proper use of the invention transferred? (e.g., manuals, face to face conversations, graduate hiring...etc.).
- *8. Was there anything that tended to inhibit the transfer process?
(these may lie in the technology, the professor, the university, your firm, an intermediary organization, or the wider environment).
- *9. How can the transfer process be improved? (by the firm, the government, the university, and organizations which link universities and firms).

10. Try to think of an example of unsuccessful technology transfer where a transfer in location, responsibility or knowledge was not achieved (or inadequate progress was made).
- Why did the technology transfer fail and at what stage?

Questionnaire

Advanced manufacturing technologies are computer based technologies that are used in product design, the production process and manufacturing planning and control (e.g. automated materials handling, computer-aided design, robotics and artificial intelligence). In this research, the scope of this definition is restricted to discrete parts manufacturing where electronic components and other materials are fabricated and assembled. For further clarification please see the attached list.

Please indicate your training and position at the company

1. The Company

a) Are you:

- _____ 1) The parent company?
_____ 2) A subsidiary?

b) Age of your company/subsidiary is around: _____

c) Your annual sales: \$ _____

d) Total number of employees: _____

i) number of employees in manufacturing: _____

ii) number of full-time R&D staff: _____

e) Percentage of R&D budget spent on AMT projects at your company/subsidiary: _____

f) Number of identifiable (AMT) inventions transferred in the last five years :

- i) From Canadian universities _____
ii) From other universities _____
iii) From other sources (please specify the source) _____
-

Please focus on the last significant AMT transfer relationship with a Canadian university

2. Which of the following had a negative effect on the AMT transfer process?

	<u>please indicate the significance of the following issues</u>				
	not at all significant	moderately significant	extremely significant		
a) University was interested in longer term research than the time frame you had in mind.	1	2	3	4	5
b) Legal constraints were different for you and the university.	1	2	3	4	5
c) Your firm's decision making style was different from the university's (e.g. meetings, authorization, etc.).	1	2	3	4	5
d) The university wanted to disseminate the research results quickly and widely.	1	2	3	4	5
e) Your view on intellectual property rights (e.g., patents, royalties and licenses) did not coincide with the university's.	1	2	3	4	5
f) The need for extra funds and staff to utilize university inventions.	1	2	3	4	5
g) Lack of communication in the university.	1	2	3	4	5
h) Lack of communication in your firm.	1	2	3	4	5
i) Lack of communication between your firm and the university.	1	2	3	4	5
j) University lacked the expertise needed to manage the transfer process.	1	2	3	4	5

	not at all significant	moderately significant	extremely significant		
k) Subjective judgement of the technology by your staff/colleagues.	1	2	3	4	5
l) University people seemed to be out-of-touch with the real world needs.	1	2	3	4	5
m) Professor was late in delivery.	1	2	3	4	5
n) Uncertainty related to research results.	1	2	3	4	5
o) The university people pursued their own agenda.	1	2	3	4	5
p) High costs.	1	2	3	4	5
q) Other (please specify and indicate significance)					
_____	1	2	3	4	5
_____	1	2	3	4	5
_____	1	2	3	4	5

3. Why did you choose to transfer AMT from university instead of developing it in-house?

	not at all significant	moderately significant	extremely significant		
a) Access to the needed expertise available at the university.	1	2	3	4	5
b) Obtain a window on science and technology.	1	2	3	4	5
c) Access to facilities and instrumentation not available to us.	1	2	3	4	5
d) Lack of in-house R&D staff.	1	2	3	4	5

	not at all significant	moderately significant	extremely significant	
e) Solve a particular problem or get information not available to us.	1	2	3	4 5
f) Improve the company's image.	1	2	3	4 5
g) Uncertainty of costs of internal development.	1	2	3	4 5
h) Expediting the innovation.	1	2	3	4 5
i) Need for demonstration of feasibility of the technology ("Look and Buy").	1	2	3	4 5
j) In-house R&D concentrates on incremental improvements at the expense of radical developments and inventions.	1	2	3	4 5
k) Other (please specify and indicate significance)				
_____	1	2	3	4 5
_____	1	2	3	4 5
_____	1	2	3	4 5

4. What criteria did you use to estimate the degree of success of the technology transfer?

	not at all significant	moderately significant	extremely significant	
a) Impact on profit.	1	2	3	4 5
b) Impact on sales.	1	2	3	4 5
c) Continuation of relationship with the university.	1	2	3	4 5
d) Meeting your technical specifications.	1	2	3	4 5

e) Your utilization of the technology by using it in-house or by selling it.	1	2	3	4	5
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f) Other (please specify and indicate significance)

_____	1	2	3	4	5
_____	1	2	3	4	5
_____	1	2	3	4	5

Thank you for your help.

Appendix 3
Summary Data For Firms Interviewed

<u>Company</u>	<u>Country</u>	<u>Type of Ownership</u>	<u>Location</u>	<u>Number of Employees</u>
1	Canada	Parent	Montreal	3,500
2	Japan	Subsidiary	Ottawa	165
3	Canada	Subsidiary	Toronto	160
4	Canada	Parent	Toronto	10
5	Canada	Parent	Hamilton	12,500
6	Canada	Parent	Waterloo	110
7	Canada	Subsidiary	Toronto	100
8	Canada	Parent	Mississauga	200
9	England	Subsidiary	Montreal	2,500
10	Canada	Subsidiary	Mississauga	680
11	Canada	Parent	Burlington	12
12	Canada	Parent	Ottawa	350
13	Canada	Parent	Ottawa	24,000
14	Canada	Parent	Ottawa	1,100
15	Canada	Parent	Waterloo	55

<u>Company</u>	<u>Age</u>	<u>Manufacturing Employees</u>	<u>Full Time R&D Staff</u>	<u>\$ Sales (millions)</u>
1	44	800	350	300
2	20	45	35	100
3	16	60	65	N/A
4	9	6	3	1
5	75	10,500	80	2800
6	21	85	3	10
7	5	80	2	35
8	18	120	40	20
9	88	2200	500	110
10	23	9	9	100
11	13	4	5	0.40
12	15	40	200	35
13	20	14,000	8,500	N/A
14	22	6	160	140
15	10	5	20	10

<u>Company</u>	<u>R&D% Spent</u> <u>on AMT</u>	<u>AMT Adoption</u> <u>/Canadian</u> <u>Universities</u>	<u>AMT Adoption</u> <u>/Non-Canadian</u> <u>Universities</u>	<u>AMT Adoption</u> <u>/Other Sources</u>
1	5%	1	0	0
2	10%	1	0	0
3	5%	4	3	2
4	20%	2	0	0
5	8%	10	5	10
6	6%	0	0	10
7	3.5%	4	0	10
8	12%	1	0	0
9	7%	1	0	10
10	1.5%	1	0	0
11	10%	1	0	0
12	10%	15	2	5
13	20%	5	5	5
14	3%	1	0	0
15	10%	1	0	0

Appendix 4
Fifteen Main Technologies Discussed

PROJECT	COMPANY SIZE	SUCCESSFUL	UNSUCCESSFUL
1	Large	Algorithm to control the motion system on flight simulators	
2	Small		Specific AMT device (laser area)
3	Small	Specific AMT device (atmospheric pressure area)	
4	Small	Data acquisition and analysis system	
5	Large	Mathematical program (steel area)	
6	Small		Specific AMT device (metallurgy area)
7	Small	Automotive component	
8	Small	Integrated circuits device	
9	Large	Integrated Optic Spectrum Analyzer	
10	Large	Simulation modelling	
11	Small		Specific AMT device (laser area)
12	Small	Sigma data convertor	
13	Large	Semiconductor chip	
14	Large	Data base	
15	Small	Compiler programming tool	

Appendix 5

Modified Scores on Incentives and Barriers

TABLE 1: AVERAGE SCORES ON INCENTIVES

INCENTIVE	AVERAGE (LARGE COMPANIES)	AVERAGE (SMALL COMPANIES)
Access to expertise available on campus	3.43	4.13
Obtain a window on science and technology	3.86	3.25
Access to facilities and instrumentation	2.86	3.38
Lack of in-house R&D staff	3.14	2.00
Solve a particular problem	3.21	3.00
Improve the company's image	2.71	2.50
Uncertainty of costs of internal development	1.93	2.50
Expediting the innovation	3.86	3.38
Demonstration of feasibility of the technology (look and buy)	3.71	2.75
Concentration of In- house R&D on incremental improvements at the expense of radical developments and inventions	3.14	2.75

TABLE 2: AVERAGE SCORES ON BARRIERS

BARRIER	AVERAGE (LARGE COMPANIES)	AVERAGE (SMALL COMPANIES)
Time frame difference	1.86	3.00
Different legal constraints	1.71	1.13
Different decision making styles	2.14	3.00
Information dissemination conflict	1.71	1.63
Ownership of intellectual property	1.86	1.25
Need for extra funds and staff to utilize university inventions	2.50	2.38
Lack of communication in the university	1.29	2.25
Lack of communication in the company	1.71	1.38
Lack of communication between the company and the university	2.00	2.38
University lacked the expertise needed to manage the transfer	1.14	2.38
Company's subjective judgement of the technology	1.57	1.75
University's lack of market awareness	2.14	3.25
Prof's delay in delivery	1.71	2.75
Uncertainty related to research results	2.14	1.75
The university people pursued their own agenda	1.86	2.63
High costs	2.21	2.00

END

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FIN