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Study of the Innovation Process in the Canadian Electronic and Telecommunication Industry: An Innovation Time Perspective

by

**Sandeep Mathur, B.Sc. Hons.(Physics)
MBA (Marketing)**

**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**

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**Study of the Innovation Process in the Canadian Electronic and Telecommunication
Industry: An Innovation Time Perspective**

submitted by Sandeep Mathur, MBA
in partial fulfilment of the requirements for
the degree of Master of Management Studies

Thesis Supervisor

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Director, School of Business

Carleton University
May 17, 1993

ABSTRACT

This thesis investigates the innovation process in firms within the Canadian electronic and telecommunication industry. Furthermore, it determines what strategies are considered important to reduce the innovation turnaround time in the industry.

From the interview results, two models were devised to describe the innovation process within software and hardware firms. The results of the self-administered questionnaire revealed that employee motivation, availability of diverse technical personnel within the firm and employee problem solving capabilities were perceived to be the most important factors in reducing the innovation turnaround time. It was also inferred that respondents categorized their responses on innovation turnaround time reduction in terms of issues related to project management of the innovation process, top management commitment to innovation, external influence on the innovation process, and the product itself.

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1. INTRODUCTION

Technological innovation is a key feature of the modern manufacturing environment and is increasingly drawing attention from many researchers. In fact, there have been a number of attempts in recent years to impose some sort of conceptual order on the innovation process, the purpose being to understand it better and provide a more secure basis for policy formulation (Kline and Rosenberg, 1986).

To highlight its importance, Cooper (1984) has suggested that with increased competition and the quickening pace of technological change, more and more firms must look to innovation as a route to corporate growth and profitability. Thus, having a successful new product program to gain a competitive advantage is the objective of many firms. But many firms miss the mark. "The new product game is similar to a horse race: ten horses leave the gate and at the end of the race, only one is the winner" (Cooper, 1986a). Furthermore, according to Cooper (1986a), new products that make it to the marketplace face a failure rate (market unacceptance) somewhere between 35% to 50%. However, at the same time, firms are increasingly depending on new product introduction for sales growth. Cooper's study further revealed that 35% of the current sales of the firms come from products that went in their portfolio within the last five years.

It is also interesting to note that half the resources that U.S industry devotes to the development and commercialization of new products is spent on products that fail or are cancelled (Cooper, 1986a). Given the high potential payoff and the significant potential losses, it is therefore very important that firms make every effort to improve the management of the game. The odds of failure are simply too high and the game is too

important to lose.

Thus, a deeper understanding of the innovation process itself and ways to improve its efficiency are critical issues faced by firms. Many models have been suggested to explain the innovation process. Summing up these models, manufacturing related innovations are considered to involve: i) basic research; ii) applied research; iii) designing; iv) prototype development and prototype testing; v) manufacturing and vi) marketing the product. In traditional linear models, also called pipeline models (Josty, 1990), these stages are considered to occur sequentially. However, most of the researchers are now of the view that the innovation process is not linear, but it is a process requiring regular feedback mechanisms between its various stages. Kline's chain linked model has explained this well and it shall be discussed in detail in the literature review section. It is also important to note that Kline's model has been the focus of attention of many researchers and multinational companies, mostly in the U.S.A and Japan, and has been constantly updated in light of the findings of the researchers. The latest addition was based on the suggestion of Yahagi and Morimoto of the Toyota Motors Company (Kline, 1990). They have suggested that knowledge, which is one of the components of the innovation process, consists not only of scientific knowledge but also of technological knowledge. The technological knowledge includes skills such as neuro muscular skills which are gained through experience on shop floor. Kline (1989) himself has said that "thus it begins to seem that the Chain-linked model has a significant degree of qualitative predictive utility".

Most of the studies on the innovation process have been conducted in the U.S.A.

Therefore, the **first objective** of this research would be to understand and analyze the innovation process in the Canadian electronic and telecommunication industry. The electronic and telecommunication industry has been selected because of its unique characteristics.¹

When discussing the innovation process, an important issue arises about reduction of the innovation turnaround time, i.e., reducing the time taken for the new product development from market finding or technology research to actual market introduction of the product.

It is widely acknowledged by researchers and industrialists that innovation time is of paramount importance. It is said that one aspect of a nation's competitiveness is assessed by how quickly that nation's manufacturing firms can innovate, i.e., develop and commercially introduce new products and processes that are central to success. Several researchers, including Feigenbaum and McCorduck (1984), Okimoto (1986) and Mansfield (1988), have dealt with the issue of cost effective speed with which innovation takes place in firms.

In fact, a study by Kumar and Kumar (1991) has found that both American and Japanese innovating firms tend to innovate more rapidly than the Canadian innovators.

¹ First, the study of Port, Schiller and Bureau reports (1990) on new product development has generated interest. They have stated "in the fast track electronic sector, the accepted rule of thumb is, the first two manufacturers that get a new generation product to the market lock up as much as 80% of the business". Second, these are young technologies which came up in the twentieth century, however, in spite of their youth, electronic and telecommunication technologies have become essential virtually in all areas of human activity (Davidse, 1983). Third, electronic and telecommunication industry is also easily accessible because of their high concentration in Ontario and Quebec (representing 69% of the total Canadian electronic and telecommunication firms).

American time advantage as perceived by Canadian innovators is in the order of 4% and that of Japanese in the order of 9%, over Canada.

The **second objective** of this study, therefore, would be to find out the strategies being adopted by firms in the Canadian electronic and telecommunication industry to reduce the innovation turnaround time to become globally competitive.

2. LITERATURE REVIEW

An examination of the literature dealing with innovations has revealed various definitions of innovation and the innovation process and many models have been suggested to explain the innovation process. The first section of this study therefore deals with the definition of innovation and innovation process. The second section deals with different perspectives from which various innovation models have been described. The third section deals exclusively with the Kline's chain linked model (with some modifications) which seems to have captured the essence of innovation process. In this section the differences between the Kline's chain linked model and Linear models have also been highlighted. The fourth section deals with the importance of the innovation turnaround time. The final section deals with the strategies to reduce the turnaround time, i.e., expediting the innovation process.

2.1 Innovation and Innovation Process

Various definitions of innovation and the innovation process have been proposed in the literature. However, the definition given by William Souder (1987) reasonably summarizes the basic idea. According to him, innovation is a high risk idea (i.e., chances of product failure are high) that is new to the sponsoring organization and which the organization believes has higher potential or other favourable commercial impacts for it. The innovation process is any system of organized activities that transform a technology from idea to commercialization.

It is also important to note that the new product development process and

innovation process shall be used synonymously, acknowledging the fact that newness or innovativeness can be defined in two ways. Newness can mean new to the company, in the sense that the firm has never made or sold this type of product before, although other firms might have. This includes new product lines, addition to existing product lines, improvement and revision to existing products. Newness can also mean new to the market or the first of its kind.

2.2 Innovation Models

The innovation process has been described from two perspectives: the perspective of the producer of the technology, i.e., producer stage or the perspective of the user of the technology, i.e., user stage. The user stage models basically are concerned with the diffusion of innovation and include the following stages:

i) awareness of a new concept; ii) idea generation; iii) matching/ proposal selection; iv) adoption or acceptance of an idea; v) preparation, which would involve developing the required infrastructure to properly maintain and control the innovation; vi) implementation, during which innovation is tried out and evaluated; and vii) routinization, when the innovation becomes part of daily practice (Souder, 1987).

This paper shall consider only the producer perspective, as the interest is to understand the new product development process.

Innovation Models (Producer perspective)

When considering the producer stage models, Saren (1984) has classified them systematically according to the taxonomy of different types, namely:

- Departmental stage models
- Activity stage models
- Decision stage models
- Conversion process models

Each model views the innovation process from different perspectives, therefore, a more detailed explanation of these would enhance the understanding of the innovation process.

I) Departmental Stage Models

In these models, the innovation process is broken down into a series of stages associated with the departments of the firms. The innovation moves from its conception as an idea through various departments sequentially, until it finally emerges into the market as a new product. The first department to be involved is R&D, followed by the design department, then the production department and finally the marketing department as shown in Figure 1. Further, Robertson (1974) noted that while innovation passes through various departments, it is affected by and interacts with the "external push" (meaning external technology) and "need pull" elements (meaning market: socio-economic needs). However, these models are too simplistic and have certain flaws associated with them such as:

- 1) Only the name of the departments associated with the new product development process are mentioned but the activities involved in this process are not described.
- 2) These models do not mention anything about information exchange among the various departments involved in the innovation process.

DEPARTMENTAL-STAGE MODEL

Figure 1

SOURCE: ROBERTSON (1974)

II) Activity Stage Models

Activity stage models are based on the activities involved in the firms' innovation process and the external factors influencing each of the activity stages of the process. These models are considered to be an improvement over the departmental stage models. In these models, the innovation process consists of 6 sequential stages which are shown in Figure 1a as i) idea generation; ii) idea screening; iii) commercial evaluation; iv) technical development; v) testing; and f) commercialization (Kotler (1976) and Backer and McTavish (1976)).

Idea generation uses various sources of new ideas which are screened in the second stage according to a number of criteria such as technical feasibility, compatibility with firms' objectives, product mix, and resources available etc. Third stage involves the application of commercial estimates regarding potential costs, prices and sales of the resulting new product. In the fourth stage, a prototype is developed which is tested in the fifth stage. The final stage comprises of activities such as development for production, test marketing and product launch.

The strengths of such models are:

- 1) The distinction between stages is clear when based on activities in this manner.
- 2) These models also tell us more about the tasks that are carried out on the innovation project within each stage.

Again, the major weakness of these models is that they give no indication of the feedback mechanism between the various stages.

ACTIVITY -STAGE MODEL

Figure 1a

SOURCE: BAKER AND McTAVISH (1976)

III) Decision Stage Models

In these models, the process of innovation consists of a series of decisions made by managers responsible for it and these decisions are made according to the quality of information available to those managers. In the Rubenstein and Ettlie study (1979), the decisions are grouped according to the effect they have on various activities or departments, such as marketing, research and development, production, and finance. They have identified key decision and action points in the innovation process but the problem with their model is that this breakdown of the process into decision points does not indicate the actual sequence of decisions. The weakness of this model was overcome by Cooper and More (1979), who split the process into decision modules which they termed as risk management modules. Here, innovation in the firm is viewed as an evolutionary sequence of modules as shown in Figure II. Each module consists of four activities, viz. i) information gathering to reduce uncertainty; ii) evaluation of the available information; iii) decision making; and iv) identification of remaining key uncertainties.

In each module, two types of decisions are involved. First, Go/No Go; i.e., should the project be continued or stopped? Second, if continued, then where to next; what further information is required and hence determine the next module. This modular approach seems to be more flexible than activity stage models, which consider each activity or function being carried out in a sequence. This approach towards innovation process has also been suggested by Twiss (1980).

The strengths of these models are:

- 1) All these models highlight the fact that the innovation process can be viewed as

a whole, in terms of inputs and outputs, i.e., both the internal and external environment are considered.

- 2) These models take into account the fact that decision points exist between various stages. In other words, at the end of each activity, a decision has to be made whether to proceed to the next stage or not. This is very important to know when substantial costs are involved in a project.
- 3) These models also provide a more practical basis for examining the innovation process by permitting the use of analytical techniques of decision theory, probability analysis and computer simulation.

Again, these models do not explain the feedback mechanisms existing during the innovation process.

DECISION -STAGE MODEL

RISK MANAGEMENT MODULES

Note: Modules are the decision units which are the building blocks of the innovation process.

SOURCE: COOPER & MORE (1979)

Figure II

IV) Conversion Process Models

Conversion process models have taken into account the fact that in practice it is very rare that innovation is so rational and ordered. Twiss (1980), has viewed technological innovation as a "conversion process" transforming inputs such as raw materials, scientific knowledge and manpower into outputs - new products as depicted in Figure IIa. On this basis, he has differentiated between the innovative behaviour of two types of firms, product oriented and market oriented. However, in each case, innovation is depicted as a conversion process. The salient feature of this conversion process model is that it makes it clear that several inputs are possible and they may take the form of activities, information and departments of the firm. Thus, it avoids the sequential approach of the other models where one stage follows another. Here the firm is represented as a user of inputs of various types, but their order is unspecified.

Schon (1967) has also described innovation as a conversion process. He views innovation as the conversion of uncertainty; which is incalculable, into risk, which is quantifiable through collection of knowledge. But this is a far more abstract model than the Twiss model.

However, if most authors seem to share the same view that the innovation process can be identified, portrayed and ordered, then the conversion process contributes less than others to our understanding of it.

One aspect that emerges clearly from the presentation of these models is that various stages of the innovation process have been clearly identified and viewed from different perspectives.

Figure 11.a

CONVERSION PROCESS MODEL

a) Product Orientation

b) Marketing Orientation

SOURCE: TWISS (1980)

2.3 Kline's Chain Linked Model (with some modifications)

Though the stages and the activities within them have been well explained in the aforementioned models, none of these models explain whether a feedback mechanism exists between these stages or not. It is Kline's chain linked model which explains not only the stages of the innovation process but also the feedback mechanisms between each of these stages, thus making it a good candidate for guiding this research. The model is shown in Figure III. Yet another reason for considering this model (as cited earlier), is that it has been generating a lot of interest among researchers and industrialists in the context of American and Japanese industries but no study has been conducted in context of the Canadian industries. In fact, a number of corporations which have used these ideas, such as the General Electric, Bell Telephone Systems and a number of Japanese firms, appear on an average to be more successful innovators (Kline, 1989).

Kline's model is basically an activity stage model, but is much more advanced in the sense that it takes into account the feedback mechanism between the different stages of the innovation process along the central chain of the innovation and also explains the feedback mechanisms between the central chain of innovation, research, and knowledge. The central chain of innovation is comprised of i) market finding; ii) synthetic design; iii) development stage (which includes detailed design and testing); iv) redesign and produce; and v) distribution and marketing. Another stage which can be added to the central chain of innovation is the new product strategy stage. These stages are briefly described below:

FIGURE III - KLINE'S CHAIN LINKED MODEL

SOURCE: Stephen Jay Kline, Figure 3, The 1989 Thurston Lecture, Report INN-3B, Thermosciences Division, Department of Mechanical Engineering, Stanford University, Stanford, California, August 1990

Note: Explanation of feedback loops in Figure III has been given in Appendix I

1) Market Finding: Market finding involves a quick market assessment, using in-house information (for example, the sales force); relying on secondary data (for example, research reports or published statistics); and accessing outside sources (potential customers or industry experts). Desired information aims to find an overview of the market, identification of possible segments, market size, and likely prospects for the new product (Cooper, 1983). This study also seeks to find out what exactly these customers want, and what the competitors are offering to satisfy those needs.

2) Synthetic Design: there are three important forms of synthetic design, namely, invention, preliminary design and analytical design. These are briefly described as follows:

Invention: The patent office defines an invention as a new design sufficiently different so that it would not have been obvious to an individual skilled in the prior art.

Preliminary Design: Preliminary design has been defined by Kline (1989) as a creation of new design, a new synthetic arrangement of the product, process or system created largely from old components or items well within the existing state of the art. These old components may be from prior models, they may come from suppliers of parts (old or improved versions), or they may be designed *ad novo* using materials and processes already well known. Essentially, the preliminary design of a complex system is a general layout of the system with only enough detail and supporting computations to make sure it is viable.

Analytical Design: Analytical design is the use of a model in order to reach optimal or near optimal designs under known constraints. In fact, with the advent of computer simulation of the products or processes, it has now become very easy to obtain optimal or near optimal designs (Kline, 1989). However, one thing that should be kept in mind is that design is just the reduction to paper (drawings) of the specific features of a real embodiment of a real machine, system or device. Further, all the three forms of synthetic design just explained above are not stand-alone processes but are supplementary, i.e., one form may be best suited to a given component and another to a second component within a larger design.

One important point highlighted in this context by Kline (1989) is that new products do not flow directly from research but, typically flow from a synthetic design, i.e., research leads to product innovation insofar as it stimulates a design.

3) Development Stage: Development stage is comprised of i) a more detailed design; ii) manufacturing of prototype and iii) performance of tests. The commercial viability is also established during this phase (Cooper, 1983). Sometimes, in parallel to product prototype technical tests, the customer tests are conducted where prototype samples are placed with potential customers for trial to test the products' design. The object is to identify design defects and do subsequent modifications. Simultaneously, the design of a formal and complete marketing plan based on the results of market finding is set. The factors decided are pricing, distribution, advertisement, sales force strategy and servicing.

4) Redesign and Produce: Redesign and produce is the actual production phase which is carried on after the design has been tested, and, if necessary, has been modified before the actual production. During this stage, pilot production run tests are also performed that will eventually be used for full scale production. Modification to the final production facilities or methods are often required in order to overcome problems discovered in the pilot production. In parallel, test marketing is conducted where the product is sold to a limited number of customers or in a limited geographic area. This not only tests the product but all the elements of marketing mix together. The two important results of the test marketing are identification of needed adjustments of the marketing plan and a final estimate of market share and expected sales. Then a final pre-commercialization analysis and business evaluation is made based on concrete financial data from test market and trial production to define specific new product roles (Cooper, 1983).

5) Distribute and Market: once the product is successfully tested by analysts and accepted by management, a GO decision is made and the launch of the new product is planned. In planning the launch, the firms have to coordinate the marketing mix and production. This coordination and timing of the launch becomes particularly crucial if competitors are also developing a new product for the target category. To have a successful and timely launch, the product advertising, selling, promotion, and distribution strategy have to be implemented effectively. The sales force have to be trained and motivated to allocate the planned effort. The channels of distribution have to be well established and wholesalers/dealers etc. have to be geared to stock display and service the

product. Advertising media has to be purchased and ad copy written. In addition, samples, brochures, and coupons have to be produced and immediately mailed. Pricing strategy should also be clear, i.e., either follow a skimming or penetration strategy. Another important task facing the companies during the launch phase is to closely monitor and diagnose the competitors' activities so that timely and appropriate action can be taken (Urban and Hauser, 1980).

6) New Product Strategy Stage: this is another stage which has been added to the new product development process models by Rodocanachi (1983) and Cooper (1986). This new stage has been described as the initiating stage of the innovation process. However, with reference to the Kline's chain linked model the new product strategy stage can be considered after the market finding stage. It involves the development of strategic roles for new products, which requires in-depth understanding of consumer problems, wants and needs; the competitive environment; the internal capabilities of the organization; the requirements to be placed on the new products; the fit of the new product effort within the corporate sector or business unit strategy, etc. Such understanding allows the new product manager to define new product roles after assessing the product is doable by the company.

This central chain of innovation is then connected to research through knowledge. The research can be of two types, basic and applied. **Basic research** is the fundamental research which is not directly related to any product or process while **applied research** represents investigation directed to discovery of new scientific knowledge which has

specific commercial objectives with respect to either products or processes (National Science Foundation).

Knowledge is part of Science which has been defined as a property - a kind of quantity that exists and can usually be stored for future use. Kline (1990) also mentions about Yahagi and Morimoto of Toyota Motors, who have found that knowledge besides comprising of scientific knowledge, (based on science), also consists of technological knowledge. Thus, the latest change incorporated in Kline's model is that knowledge is shown to consist of both the scientific knowledge and technological knowledge where technological knowledge is defined as knowledge which arises basically from the shop floor, and gets imbibed in practice. It is gained from experience such as neuromuscular skills, rather than formal learning. Furthermore, this is not reducible to paper or computer programs and, therefore, does not get published, but in reality it does exist as part of knowledge, which aids in the innovation process.

Thus, after considering all the possible stages of the innovation process, it seems that with some modifications to the Kline's Chain linked model, the new chain linked model is more comprehensive. The new chain linked model will serve as an *a priori* model for this research and has been shown as Figure IV.

APRIORI MODEL

Figure IV

Based on various models just described, many differences that can be highlighted between the linear models and Kline's chain linked model are as follows:

- 1) In a sequential or a linear model, there is only a vertical flow of information, where the innovation process performs in the framework of hierarchical organizations with the bureaucratic command and control concept of management. Chain linked models, on the other hand, have a more effective communication mechanism, as they are based on horizontal communications across departments and inter-organizational boundaries at the peer level, thus doing away with many bureaucratic hurdles (Bush and Frohman, 1991). Port, Schiller and Bureau reports (1990) have also cited practical examples to demonstrate that instead of passing the information from one level to the other with management approval at each stage, there are teams set up in firms which communicate electronically and make decisions themselves. Examples are that of Kodak's Engineering system division and Motorola corporation's radio telephone plant in Schaumburg, Illinois, where management hierarchy has been trimmed from seven tiers to four.
- 2) In the linear models, research monopolizes the entry gate to the total process of innovation whereas in the chain linked model, research is not normally the initiating step but it is the market finding, i.e., assessment of what might improve a given product or system or provide a new product or system that meets an unfulfilled market (use). This follows from the fact that if no market (or use) exists for a product, innovation by definition will not occur. However, in the Chain linked models, important areas of research typically are present in several downstream arenas of action as well as sometimes occurring in the initiation step.

3) Linear models are implicit in the argument about technical push as opposed to market pull: to have a push or a pull implies a process with a beginning or end, but the distinction between pushes and pulls loses all meaning in a looped process, because every cause becomes in due time an effect and every effect becomes in due time a cause (Kline, 1989).

4) The Linear models are uniflow and have no indication of feedback loops, whereas the Chain linked model incorporates many forms of feedback, which is very essential because the more rapidly the environment changes, the more rapid feedback is needed. Further, these feedbacks are necessary for evaluation of performance, for formulation of the next steps forward, and for assessment of competitive position. The various kinds of feedback mechanisms which the chain linked model considers whereas the linear models do not are as follows:

a) A feedback mechanism between designing, testing and manufacturing: all three departments are involved early in the design of the product. Since the design engineers must know what is necessary to make a testable design, the test engineers therefore must be involved early in the design process to avoid discovering testability issues downstream when they are more expensive to fix. Further, to achieve a better coordination between designing and manufacturing departments, many firms are now considering the Process Capability Index C_p , as a good method for both design and manufacturing engineers to attain quality goals jointly by having both sides work together. The design engineers open the specifications to the maximum possible, while permitting the product to operate within customer expectations, while the manufacturing engineers reduce the process

variation by maintenance and calibration of process and materials. It is thus important that the design department should not estimate the levels of manufacturability, testability, reliability etc. on its own, but should insist on feedbacks from respective departments to avoid a mismatch between performance requirements of a product and manufacturing capability. Another way in which the manufacturing department can give feedback to design department is by using and developing software tooling whenever possible, to allow the manufacturing department to build all prototypes. When making prototypes, manufacturing should record all discrepancies in assembly and fabrications, violations of manufacturing equipment or process constraints, documentation errors, parts misalignment and all parts failures. This manufacturing feedback should be supplied immediately to the design department together with the prototypes, with suggested design changes (Shina, 1991). To facilitate the information exchange and teamwork spirit between the designing and manufacturing departments, Westinghouse Electronic System group has put these departments under one manager. Further, shop floor laboratories have been set up which are outfitted with the same equipment that will be used for production. These labs are a meeting ground for the teams from the designing and manufacturing departments to prove out the designs (Port, Schiller and Bureau reports, 1990).

b) Chain linked models also take into account the feedback mechanism between marketing, designing and manufacturing departments. Many tools and techniques are suggested to achieve an early link between these three departments. One such tool is the Quality Function Deployment (QFD) maps. This is a graphical method which places the customer requirements (obtained by marketing department), engineering requirements and

manufacturing requirements with respect to proposed project onto a common matrix, so that interactions and conflicts can be identified and discussed by project team members at an early stage (Hippel, 1990; Shina, 1991). It is also interesting to note that as technology grows more comprehensive, designers are approaching the capability to produce virtual prototypes that employ all aspects of the product. It will eventually be possible to model the user interface of a product so that customers can interact directly with the virtual prototypes. These feedbacks can be incorporated into QFD maps which help redirect the design to accommodate their suggestions (Shina, 1991).

c) Yet another kind of chain linked process possible is due to market feedbacks which may result in long range research.

d) Lastly, sometimes after launch phase there are customer feedbacks which require assessment of product utility and competitiveness. This is done by market finding and is incorporated into planning and design of subsequent models or new systems for a given purpose. In addition, deficiencies discovered in service offered by the product after its introduction into the market may require work in any or all of the prior stages along the chain of innovation.

Thus, the Chain linked system appears to be a useful source of thinking about effective management of corporate innovations as it suggests specific attention to creation and maintenance of rapid, effective feedback links at many points in the system (Kline, 1989).

2.4 Innovation Turnaround Time

The next important issue is to study the strategies to reduce the innovation turnaround time or increase the speed of innovation process.

In the literature, the importance of innovation time relative to innovation cost is emphasized as a competitive weapon. The firms that bring new products to the market first, gain market share, have an opportunity to modify products in response to customer demands and play a leadership role in the market. In fact, due to time based disadvantage, many North American companies are losing leadership in technology and innovation (Stalk, 1988). Thus, it would be extremely useful to explore the steps undertaken by the Canadian electronic and telecommunication firms to reduce the innovation turnaround time to become globally competitive.

2.5 Strategies to Reduce Innovation Turnaround Time

A number of strategies have been suggested in the literature to reduce the innovation turnaround time. These include:

- 1) Top management role:** top management plays an important role in increasing the speed of the innovation process by ensuring the following:
- a) creating an atmosphere for generating interest and action of the employees by showing regular and keen interest in the project and supporting them;
 - b) making provision for good communication within the organization (i.e., both horizontal and vertical communication);
 - c) having less bureaucracy to remove unnecessary procedural hurdles;
 - d) ensuring high motivation of employees through incentives, work recognition and

appreciation; e) quick decision making and hence giving quick feedback as and when required and f) ensuring the employees perceive that the climate is non threatening, but there is a sense of urgency to develop new things.

Thus, the top management support and vision is critical to reduce the turnaround time of the innovation process (Pearson, 1990; Brown and Karagozoglu, 1989; Voss, 1984; Taylor, 1990; Smith, McKeon, Boysen and Shechter, 1984).

II) Technological sophistication: various stages of the innovation process can be expedited by the use of sophisticated technologies. The options that the firms have to reduce the turnaround time include:

- a) Automation of material handling for improving the logistic process.
- b) Automation of design process through computerized design process technologies such as Computer Aided Design (CAD), Computer Aided Engineering (CAE). CAD, CAE and sharing of a common database can not only greatly facilitate the design process but also ensure compliance with design standards and even check design performance and producibility before production phase (Lee, 1991).
- c) Automation of manufacturing process through CAM.
- d) Computerized aided inspection and testing (Meyer, 1991).
- e) Use of Rapid Manufacturing Technology (RMT): Queuing theory based RMT can be used for rapid evaluation of alternatives such as effects of lot size, set up times, equipment choices, staffing alternatives, production rates, work in process

and lead times and thus provide valuable feed back on critical processes and equipment needs which removes sources of delays in projects (Suri and Treville, 1990).

f) **Integration of synthetic designs with the testing programs.** It can also greatly reduce the number of expensive tests required, improve the details of the design study of critical components or functions, and thus increase the development speed and/or reduce costs while simultaneously creating a better end product (Kline, 1989).

However, the key to success is that sophisticated technologies should be used with a high degree of synergy with the firms resource base (Cooper, 1984).

III) Better Planning: the best way to plan a project is to divide it into tasks and subtasks. A completely partitioned project enables one to see all component tasks and subtasks interfaces specified implicitly or explicitly, so that all would fit and work together to form the total project when combined. Project managers specify tasks and their interrelationships so that they can distribute innovation effort across people and organizations, both in series and parallel with respect to time (Hippel, 1990). A focused approach towards a project has also been recommended by Drucker (1985). In fact, strategic focus was found to be a statistically significant variable explaining productive efficiency in Baron's study (1990). Further, as the tasks are partitioned, monitoring techniques such as check points, decision points or gates (Cooper and Kleinschmidt, 1991) are also planned simultaneously, which shall enable to identify areas where problems

might arise. Once the problem areas are identified, preventive or standby measures can be taken to prevent the project coming to a sudden halt. It is important to note that task partitioning need not be completed prior to the start of the project work, it may appropriately proceed as the project itself proceeds (Hippel, 1990).

Even in manufacturing processes, divisibility is considered to be one of the most critical attributes of an innovation. Taking advantage of divisibility is a coping strategy for reducing uncertainty. It contributes to reducing technical complexity by making the problem handled at each stage more manageable and thus help in expediting the entire innovation process (Gerwin, 1988). Task partitioning can also help in establishing strong interfaces between marketing research and R&D, between product design and process design etc. A two way communication is required to improve performance at these interfaces i.e., there should be a joint problem solving across the boundary in order to move the project smoothly (Hippel, 1990).

IV) Organizational Dynamics: organizational design and environment (corporate climate) are key to fostering innovation. Various organizational structures and intra organizational activities have been suggested to reduce the turnaround time of the innovation process. Some of them are:

a) Formation of cross functional teams: many highly innovative enterprises emulate small companies' practices by using cross functional teams comprising of representatives from different departments involved in the new product development. Quinn (1985), has addressed this team approach with regard to technical aspects of the

product as "skunk work" approach, where small teams of engineers, technicians, design and model makers are placed together with no intervening organizational or physical barriers to develop a new product from idea to commercial prototype. The skunk work approach eliminates bureaucracies, allows fast unfettered communications; permits rapid turnaround times for experiments and instills a high level of group identity and loyalty. Eastman Chemicals Division uses a similar concept as skunk work approach. They have set up a project team which is composed of representatives from R&D, manufacturing, marketing and other functions necessary for faster completion of the project. This team is responsible for the project from inception to commercialization (Coover, 1986). 3M Corporation also has this kind of internal venturing policy, where they have a New Business Development division responsible for evolving, nurturing and maintaining new and diverse activities through the various stages of its development (Iyer and Ramaprasad, 1984).

b) Personnel orientation: movement of production personnel to the lab/pilot plant for training before plant start up and R&D personnel to the plant for start up is yet another project expediting procedure during the process of new product development (Smith, McKeon, Boysen and Shechter, 1984).

c) Fulltime dedicated personnel: the personnel involved in the innovation process should devote their entire time to the project, in order to expedite it. However, it has been observed, specifically in small and medium sized firms that personnel devote time to a new project as and when available from their routine engineering and/or production work (Kumar and Kumar, 1991).

d) Better links with customers: in case of speciality products, direct communication between R&D and the potential customers, technical personnel also helps in expediting the innovation process as chances of misunderstanding of specifications etc. are reduced, which in many cases are a source of delay.

e) Parallel Processing: here, the process development and market development proceed concurrently with product development. This provides flexibility in making quick and right decisions which are critical for moving the project faster (Cohen, 1988). In fact, Takeuchi and Nonaka (1986) have emphasized an integrated approach which is built on the concept of overlapping of development phases. The advantage of this is, if a bottleneck appears in one stage, the process does not come to a sudden halt as would have happened in a sequential approach. Here, the overlapping phases enable the group to absorb the vibration or noise generated throughout the development process and hence the team manages to push itself forward by generating quick solutions. This process has been compared to a "Rugby Game" by Takeuchi and Nonaka (1986), where a team tries to go a distance as a unit, passing the ball back and forth according to the demands of the situation.

V) Better relationship with the suppliers: one third of the delays in product development, according to Wilkes and Norris (1972), are due to tardy delivery of supplies and services. To overcome this problem, the suppliers should be involved in the design of components and this can be done through subcontracting of design etc. "Having the right relationship with your vendor is absolutely fundamental" says Kfoury, President of

IBM's Industrial sector division. He further adds, "if you hold your vendor to the same standards (of quality, timeliness and manufacturability) and provide him with the same tools, then it doesn't matter whether you do it or the vendor does it". It becomes an economic decision as to who can do it best. Involving suppliers more closely has paid off for Ford Motor Company and Xerox Corporation (Port, Schiller and Bureau Report, 1990). Thus, the product development cycle time can be shortened by taking a system view of the innovation process, involving suppliers and vendors through subcontracting in the development process (Hippel, 1990).

Most of the Japanese firms are strong advocates of strong relationships with suppliers and they have a system called the "Sashimi" system (Sashimi is slices of raw fish arranged on a plate, one slice over the other) which requires extensive interaction not only among project members but also with suppliers. Each side regularly visits the other's plants and keep the information channel open at all times. This kind of exchange and openness both within the project team and with suppliers increases speed and flexibility of the innovation process (Takeuchi and Nonaka, 1986).

VI) Trade off between internal and external production: firms should produce only the critical components internally and buy readily available standard components from an outside vendor. This is a fact gathered through experience, where it is realized that it is harder to negotiate with the division manager in the same company to make components for you on time and at target cost. The conflict can get all the way up to the board level and produce a years' delay. A vendor, on the other hand, is faced with

competitive threats to his survival and thus has to listen to you rather seriously and carefully (Ohmae, 1985).

VII) Quality of Human Resources: the existence of a diversity of qualified experts who can be quickly called upon for help to overcome a variety of unexpected barriers that may arise during the course of innovation process is a major asset for the company. These experts act as time saving mechanisms in the innovation process, as they are expected to have a deeper insight and better project management capabilities.

Past experiences of the individuals who are responsible for carrying out innovative activities in the organization is also important for expediting the innovation process (Brown and Karagozolu, 1989). Further, training programmes and HRM activities aimed at increasing the workers' problem solving capabilities and flexibility will help in reducing the new product development time (Meyer, 1991). This has been addressed as an investment in *Human Capital* by Hull, Azumi and Hane (1984).

VII(A) Decentralized budget and availability of sufficient funds: both these factors give more instant decision making power to the departments involved in the innovation process to buy the necessary and perhaps the latest equipment, machinery etc., which would aid the project. It would also enable them to have cash reserves to replace equipment etc., in case of unexpected breakdown and thus prevent delay in completion of the project. Further, interdepartmental conflicts over money may be overcome by a decentralized budget which would help move the departments in unison. This is again

essential for expediting the innovation process (Kumar and Kumar, 1991).

IX) Strength of marketing communications and launch effort: a highly motivated and strong sales force, extensive and well planned advertising, promotion and distribution efforts can help in bringing the new product faster to the market and also increase its rate of acceptability, thereby expediting the commercialization phase of the innovation process (Cooper, 1979).

X) Government policies: ensuring less bureaucracy in terms of reduction of testing procedures that are often outside the direct control of the innovating firm is one of the ways in which the government can support firms in reducing the turnaround time. Further, setting up of technical bodies to assist firms having production/ manufacturing related problems is yet another way in which firms can be helped to prevent delays in the new product development process. Government can also extend financial support by giving loans at low interest rates for buying critical capital equipment, etc., which would aid in expediting the innovation process of the firms (Kumar and Kumar, 1991). Sprague (1986), has also suggested that it is important that the firms evaluate government supported R&D programs as part of their overall strategic thrust especially when the projects are very risky.

Building on background knowledge, this study explores the process through which innovations are carried out by the firms in Canadian electronic and telecommunication industry and what strategies the firms are using to reduce the innovation turnaround time.

3. RESEARCH OBJECTIVES

Based on the literature review the pertinent research objectives that shall be addressed are:

- 1) To understand and analyze the innovation process in the Canadian electronic and telecommunication industry based on the *a priori* model² (Figure IV) for the innovation process.
- 2) To determine the relative importance of the strategies these firms have adopted to reduce the innovation turnaround time.

² This *a priori* model has been developed based on the literature search. It has been used for framing the questionnaire to get responses for the first research objective.

4. RESEARCH METHODOLOGY

This section is concerned with the steps undertaken to conduct the research study. It is divided into 4 sub-sections. Section 4.1 discusses the research design and the research strategy. Section 4.2 describes the sample selection procedure. Section 4.3 provides a detailed account of the data collection method. Finally, Section 4.4 presents the pretest results.

4.1 Research Design and Research Strategy

The research design used in this study is an Ex Post Facto Design wherein the researcher makes no attempt to control or manipulate the independent variables under study. The research strategy is an Exploratory Single Industry Study, where the primary goal of the researcher is to increase his understanding of the process under study. A Primary Data Collection method was used for the purpose of this study. For the first objective, the exploratory study involved personal interviews with the senior manager responsible for new product development in their firms. For the second objective, the survey instrument employed was a self-administered questionnaire.³ Most of the respondents were senior managers, at the level of Vice-President Engineering, Director of Engineering or Project Manager.

³ The questionnaire was designed based on guidelines set by Dillman (1978).

4.2 Sample Selection

The electronic and telecommunication firms were selected from the Business Opportunity Sourcing System (BOSS) database of the Department of Industry, Science and Technology, Canada. The BOSS database has information on Canadian manufacturing firms, including electronic and telecommunication firms that actively pursue R&D activities. Firms were also selected from a list of hi-tech firms published in the Ottawa Citizen.⁴

These two sources generated a list of 70 medium size firms⁵ actively pursuing R&D in the electronic and telecommunication sector in Ottawa and Montreal. For the purpose of the study, the firms were selected based on the following criteria:

- 1) The firm should be a manufacturer of standard products and not customized products.
- 2) The firm should have introduced a new product or a substantially improved product in the last 2-3 years.
- 3) The product should also have been in the market for at least 6 months to ensure its market acceptability.

Typically, the size of the firm was confirmed with the receptionist, who was then asked to direct the call to a project manager or a manager responsible for a recently developed product. It usually snowballed from one manager to another. All these

⁴ The Ottawa Citizen, March 07, 1992.

⁵ 1. Only medium size electronic and telecommunication firms were selected to ensure uniformity of data collected.

2. Firms having employees between 75-500.

persons were explained the purpose of the study and the firm selection criteria. In case the firm met the selection criteria, the first available manager, who qualified to answer the questions of this research study, was asked for an interview. Subsequently, an appropriate date and time was fixed for the interview. The respondent was also asked if the interview could be tape-recorded.

In all, 22 interviews were conducted out of 70 firms contacted; 19 of these interviews were tape-recorded. The remaining 48 firms could not be included because 5 firms refused to participate, 40 firms did not satisfy the criteria of firm selection and in remaining 3 firms, the managers could not be contacted.

It is also important to note that considering firms in Ontario and Quebec can give a good idea of the Canadian electronic and telecommunication industry innovation patterns, as these firms represent 69% of the total electronic and telecommunication firms in Canada (Source: BOSS Database).

4.3 Data Collection Method

At the beginning of the interview, a letter from the thesis supervisor, as shown in Appendix II, explaining the purpose of the research and ensuring confidentiality of the information was presented to the respondent. In order to keep the discussion in focus, a skeleton diagram of the conventional linear innovation process (Figure V) was shown to the respondent.

The questions asked, along with the probes used for the first research objective are listed in Appendix III. To attain response for the second objective of the research, i.e.,

Figure V

SKELETON MODEL OF THE INNOVATION PROCESS

to determine in terms of relative importance what strategies these firms have adopted to reduce the innovation turnaround time, a questionnaire was administered after the interview session. The respondent was free to clarify any question in the questionnaire. This questionnaire consisted of all the factors leading to turnaround time reduction and the respondent was asked to rate them on a 5 point itemized rating scale. At the end of the questionnaire, the respondent was asked to state any other missing factors relevant to innovation turnaround time reduction. The questionnaire is shown as a part of Appendix III. The interview and the administration of the questionnaire took place in a single session lasting between 45 to 75 minutes.

4.4 Pre-test

First, a Pre-test was conducted with one Ottawa-based electronic firm, to help identify any problems which might arise while doing research and also to assist in revising the questionnaire. The Pre-test did not result in any significant improvement in the research instrument.

4.5 Observations

Telephone conversation with the managers revealed that firms are realizing that being innovative is very important. Even the respondents who could not participate in the study demonstrated a clear understanding of the need to be innovative. Comments of two respondents are recapitulated as follows:

- "Ours is not that innovative a company. We haven't launched a single new

product in the last 5 years."

- "We are still moving in that direction (towards innovation), so right now we wouldn't be a good example for your study."

5. DISCUSSION OF RESULTS

The results of this study are presented in two subsections. The first section deals with the description of the innovation process in the Canadian electronic and telecommunication firms; the second section deals with the evaluation of the strategies considered important for reducing the innovation turnaround time and determining the interrelationship between these strategies.

5.1 Description of Innovation Process

This section deals with the first research objective i.e., to understand and analyze the innovation process in the Canadian electronic and telecommunication industry. During the course of the interviews some pattern of differences was observed in the innovation process of the software and the hardware firms. This stimulated further investigation. Once these interviews were transcribed, a closer examination helped in finding the distinct differences between these two types of firms. The innovation process for the hardware firms⁶ is described in Section 5.1.1 and for the software firms in Section 5.1.2. Observations other than the stages of the innovation process in the software and hardware firms have been highlighted in the conclusion.

To represent the qualitative data on innovation process in the form of a model, the approach adopted has been based on the principles of matrix thinking and inductive research. The idea being to reduce lengthy verbal responses to essentials and then grouping them into well-defined categories. Patton (1981) has discussed that matrix

⁶ 2 out of 18 hardware firms were not considered for the qualitative analysis because the respondents described the innovation process for customized products.

thinking could be used to organize, arrange and analyze qualitative data. According to him, the power of matrix thinking resides in the simplicity of the tables created. Further, he has highlighted that matrix thinking is common in social sciences generally and evaluation specifically.

Mintzberg's (1979) discussion on inductive research is also very relevant to this research. He has compared inductive research as a detective work, where one tracks down patterns and consistencies. The study of Mintzberg, Raisinghani and Théorêt on model development, provided insight into analyzing qualitative data. The concept used by Mintzberg, et al. (1976) was that of a flow chart, wherein seven distinct phases of the strategic decision making process were delineated and the sequence of the stages along with the feedback links was presented in the form of a model. This research follows the similar methodology.

First of all the responses were transcribed, and then categorized according to the stages of the innovation process as identified in *a priori* model (Figure IV).

The next step was to determine the starting point of the innovation process. This could be technology research, i.e., the idea was internally generated from the R&D department or it could be market finding through customer feedback i.e., idea was externally generated. Table 1 (Appendix IV) was used to record the starting point of the innovation process for the respective firms. Similarly, it was queried whether the firms looked at the strategic role of the product before developing it and whether the firms had advance marketing activities for the product; the responses were recorded in terms of Yes and No on Table 1. Then, the responses for all the firms were summarized as shown in

Table 2 (Appendix IV).

The next task was to determine, what kind of feedback mechanisms existed between the stages of the innovation process for each firm. For this, a matrix form, as shown in Table 3 (Appendix IV), was used. This matrix table highlighted 16 possible linkages between each of the 7 stages of the innovation process as shown in the *a priori* model. Based on the transcribed interviews, these linkages between the different stages were identified and summarized as shown in Table 4 (Appendix IV). Finally, the two summary tables were used to develop two general models; one model presented the innovation process in the hardware firms and the other in the software firms. These models are shown in Figure VI and Figure VII respectively.

5.1.1 Innovation Process in Hardware Firms

This section discusses the stages of the innovation process and the feedback mechanisms for the hardware firms.

Market finding stage

The research study revealed that for the majority of the firms (56%), the starting point for the innovation process was market finding. This is quite consistent with the Kline's chain linked model, where market finding was the starting point rather than R&D. The market finding was essentially triggered by the market conditions. Either the need was felt to expand the market share, or to maintain the market share, in the face of increased competition.

Since the firms were catering to industrial customers, the primary source of

information for these firms were the customers themselves. The information from these customers was essentially obtained by the sales-people of the firm. Most of the existing customers suggested either addition of new features or price reduction. Therefore, the products described by the respondents were spin offs of the older products or of existing technology within the firm.

One firm also tried to explore the products of other firms in the market which were based on its technology. Later the firm would come up with a new product with additional features. In another firm, the marketing functions were decentralized globally; geographic area offices were responsible for handling market, sales and support in their areas in an autonomous way. However, these offices would provide input to the Corporate Product Management Group at the head office. These inputs were used to formulate future plans and actions for new product development. Some firms also utilized information from professional market research groups, conferences, etc.

Technology research stage

Market finding was followed by technology research. Technology research, in firms was performed by the Engineering department or Research & Development department (R&D) or Research & Engineering department (R&E). The majority of these firms pursued applied research, i.e., the research was conducted for commercial use only. Generally, the research group acted on the idea suggested by marketing department to determine its technical and commercial feasibility. R&D then suggested more than one design alternative and waited for the feedback from the marketing department. This kind

of regular interaction between R&D and marketing occurred in 75% of the firms which demonstrates that firms ensure their product is built upon its technological strength and the actual requirements of the customer needs. Once marketing and R&D reached a consensus, the R&D department finalized the product specifications and estimated the development cost, the unit cost and cost to customers. They also estimated the development time.

In some firms, the technology department traced the trend in the industry and determined the market need. Sometimes, the firm worked in close contact with the potential users to come up with a product or a solution which would benefit the whole industry. This kind of information exchange between R&D and customers was reported in 38% of the cases.

In three firms, the technology and marketing departments both interacted with the customers. The technology team discussed the technical issues with the customers whereas marketing team discussed the price, delivery and other business arrangements.

One firm said that if the knowledge was limited, then it went to the University or Industrial Research Centre for more information.

New product strategy stage

Once marketing and R&D reached a consensus about the technological feasibility of the product, the strategic role of the product was determined. 44% of the firms tried to assess the situation 3-5 years from now, by undertaking what they termed as a sanity test or feasibility study or business analysis. Generally, the firms accepted that they were

making an investment which might not pay off immediately, but would be profitable in 2-3 years from now. They also realized that if their firm didn't come up with a particular new product, the competitors would take over, which would in turn affect the sales of other products in the product line. One respondent said that they have a policy to undertake both short term and long term projects. Short term projects were primarily undertaken to upgrade the product line. This was done to keep pace with rapidly changing technology, and market demand in the industry. Long term projects were undertaken when it seemed that the product had potential growth capability. The business situation was analyzed in most of the firms by holding brainstorming sessions which could be either formal or informal. Departments and managers involved in this analysis varied from firm to firm. However, major participants were the owners, and heads of engineering, R&D and marketing. In one firm, they had a special group called the Engineering Productivity Group which coordinated these sessions to keep the discussion in focus.

In general, the issues that were mainly discussed were: what does the product look like in terms of its features; how has the market changed since the firm started; where would the industry be in future; how does the proposed product address that future market; how much will it cost to manufacture; does the firm have the money and infrastructure to develop the product; is it justified for the firm to spend the money to develop the product; how many units can be sold and at what price; how long will it take for the product to prove profitable; what will be the impact of the product on other businesses i.e., how will it fit the overall product line; how will it help to sell other

products of the firm; what competition will it face in future, etc.

Sometimes, if the product did not qualify on all the criteria used in the business analysis, then the firm looked for possible improvements. Some of the factors reconsidered were: how could the expenses be reduced, what additional features could be added at minimum cost to increase the sales, etc. Thus, at least 2 or 3 meetings were held before all the departments came to an acceptable agreement and got top management's approval. After this, all the findings were consolidated in order to define the product in terms of its specifications. At this point, the overall schedules, manpower requirements, etc. were also specified. Thus, the firm spends more time in the beginning only to define the product's features, performance, costs etc. It also determines the resources and efforts necessary to achieve the desired results. This is possible because all the departments get involved right away.

Designing stage

The activities at design stage fall under the purview of the engineering/R&D/R&E department. These normally comprise of two steps, preliminary design and detailed design. In some firms it was easy to distinguish between the preliminary design and the detailed design, whereas in the other firms the respondents described it as a one step process. These two steps are explained below.

Preliminary Design

This stage basically involved paper drawings of what was going to be built. The preliminary design was then subjected to a design review called the Preliminary Design

Review. This was conducted by senior managers from the engineering, production and marketing departments. The review meeting was chaired by V.P Engineering or Director Engineering. Each department had its own role and interest in the new product development. The engineering department wanted to make sure that the design included its original intent, whereas marketing ensured that there was a provision for maximum number of customer features, and manufacturing looked into the manufacturability aspect of the product. One firm had the policy of conducting a "producibility audit". In this audit, the production department was interested in knowing what new processes had to be learnt to settle the new product. They wanted the product to be designed in such a way, that if need be, it could be modified at the production level. Testability and reliability issues were also investigated. Since only 50% of the firms reported involvement of the production department at the designing stage therefore it can be stated that this observation is very firm specific. One of the reasons for this observation could be, as one manager admitted, that engineering and the production department in his firm were deliberately kept apart due to company politics. In fact, the two departments were located across the road. He felt that this had a negative impact on the new product development process. Other respondents did not give any reason for no interaction between the engineering and manufacturing departments.

Detailed Design

The preliminary design was followed by detailed design, which in some firms was also termed as "critical design". Basically, detailed design for hardware involved putting all the circuits together.

In one firm there was no paper or schematic design. Instead, it used a tool called "synthesis tool", where straight from the specifications, a circuit was written. Some respondents also explained about system simulation, which involved the integration of hardware with software. A system integration test was also conducted to test the design, in order to simulate the piece of equipment in the worst possible operating environment.

The detailed design review primarily involved production, Q.A. and engineering. Marketing sometimes participated to know if there were any changes made since the preliminary design review, or if some more features could still be added. If new features were agreed to be added, then one went back to preliminary design. Since changes at this stage cost little, most firms reported to incorporate more features at this point. Both the preliminary design review and the detailed design review were documented. Most firms continued to conduct formal or informal internal design reviews periodically. In 44% of the firms, Q.A. was active at the designing phase. At the design stage, three firms also reported the concept of peer (or "buddy") reviews within the engineering. These were conducted to ensure integrity of the design where colleagues not directly involved in the project gave their unbiased opinions. It was considered a part of quality system in these firms.

Prototype stage

Once the design had been scrutinized, a prototype was developed. Prototype is the trial model of the final product which would be delivered to the customer.

This prototype was subjected to certain tests to ensure all features were

incorporated in the model and that it was manufacturable. Tests were also conducted to look into the reliability and serviceability aspects of the product. In 62% of the cases, Q.A. played an important role at the prototype phase. To ensure reliability, quality assurance group performed life tests/stress tests, where the product was stretched beyond its design limits to see the ultimate limit. On the basis of the results, they developed the upgrading performance envelope for the product. The prototype was also shown by the design group to the servicing department to look into the serviceability aspect of the product. Based on the problems detected, the prototype was redesigned.

The customers were also involved at this stage for field trial. This was observed in 75% of the firms. The interface for the firms with customers at this point was the marketing or the customer service department. Firms gave prototype to the customers to assess whether the product met the customers requirements. These customers provided feedback directly to engineering which served as a pre-qualification of the product by limited customers. The testing of the prototype at the customer premises has been termed as "beta testing" by many firms. Only minor changes suggested by the customers were incorporated in the present design. Feedback in the form of major changes was used for the future versions of the product. Thus, the customer feedbacks gave an indication whether the firm had actually met market expectations or not. A few customers placed confirmed orders at this stage.

A cost analysis was also performed at the prototype stage to justify every feature and see if there was any further need to add/modify features. In 87% of the firms the product was redesigned at this stage.

Pre-production stage

Pre-production normally meant the pilot run, where only a few pieces were produced. It was the first time the product hit the production line. At this stage, firms reported a lot of interaction between the manufacturing and engineering. The aim being to put everything together quickly to mass produce efficiently at a reduced per unit overhead cost. In case, mistakes were detected then the trial lot was sent back to the designer for debugging. This was reported only in three firms. The criteria of pre-production varied from firm to firm. In one firm, 5% of what the company expected to produce in 1 month was produced as the trial lot while in another firm, arbitrary number of units were produced as a first lot.

In many firms, pre-production started after a few orders had been obtained. 44% of the firms reported customer involvement at the pre-production stage. Marketing also became very active at this point in procuring more orders.

Production stage

Once the pilot production run proved successful and more orders were procured, then full scale production started. Two firms sub-contracted their production.

As explained earlier, role of manufacturing was not only at the product completion stage, but it was involved in many upfront activities as well. Production and engineering department had formal monthly meetings and frequent informal meetings during the development process.

Within production, testing was reported to be an important activity. In 44% of the

cases, Q.A. was involved at the production stage. The remaining firms, reported having a testing department. They verified the products at the end of the production line to make sure that all specifications were adhered to and the products worked properly.

Product launch stage

The final stage of the innovation process was the launching of the product in the market. This was also the last and an integral part of the marketing activities, which carried on, parallel to the product development process. At this stage the firms efforts were directed in procuring as many orders as possible. Elaborate description of this stage, in terms of planning of sales force territory allocation, distribution network, advertisement frequency etc. could not be obtained as the respondents were mainly from the engineering department.

Based on the preceding description of the innovation process in the hardware firms, a chain linked model as shown in Figure VI was developed.

Figure VI

Note:
Thick arrow denotes feedback observed in more than 50% of the firms
Thin arrow denotes feedback observed in 40% to 50% firms
Dashed arrow denotes sequential link

5.1.2 Innovation Process in Software Firms

Only four⁷ software firms could be included in the sample size which met the criteria of the study. However, efforts have been made to understand the innovation process in software firms and see if any significant difference existed between the software and the hardware firms.

Market finding stage

In 3 out of 4 firms, market finding was the starting stage of the innovation process reflecting that marketing department is an important source of new ideas in the software firms. New versions of the software packages were based on the customer suggestions or problems faced by them. In one firm, customer feedback was obtained not only by the sales group, but also by the customer service group and the product development group. The information obtained was entered onto a database which formed the basis for necessary actions. Another source of information utilized by this firm was its quarterly newsletter, which contained a form for customer suggestions. This feedback was also stored on the database. One firm reported that due to intense competition, it was forced to come up with a new software.

⁷ Initially, interviews were not scheduled based on a classification such as software firms and hardware firms. Later, it was not possible to include more software firms from Ottawa area in the sample because they did not satisfy the selection criteria. Software firms from Montreal and Toronto were not contacted due to time and budget constraints. Thus, the sample size was limited to 4 software firms.

Technology research stage

Again in software industry, much of the technology research conducted by the firms was applied research. Technology research was performed by Research and Development (R&D) or Research and Engineering (R&E) or Engineering department. Based on the feedback from the marketing, the R&D worked on the feasibility of the idea. A regular interaction between the R&D and marketing was reported in two out of four firms. Once the R&D felt that the project was doable, they planned the budget, manpower etc. Further, in two of the responding firms, R&D interacted with the customers.

Based on the agreement reached between the R&D and marketing, the R&D prepared the product specifications. One firm reported that some of its existing customers who were interested in buying the new upgraded version of the software, sent their technical people to its premises. These technical people were trained in advance by the supplying firm so that it would be easy for them to adapt to the upgraded version of the product. During the training period suggestions of the users for any modification were also noted down by the supplier firm. These suggestions were then passed on to marketing, to determine the impact on the product sale. One firm said it utilized research done by other research institutions such as the universities.

New product strategy stage

Surprisingly, only one out of the four responding firms reported having formal strategic planning. One of the prominent reasons could be lack of resources, as one

respondent had said, "we would like to have a formal strategic plan in our firm, but we do not have the expertise or resources within the firm".

Designing stage

The designing stage began once R&D had written the specifications. Again, there was no fine line of distinction between the preliminary design and the detailed design. The software design document gave the blue print of the product. This document went through a review, to ensure it actually represented the requirement and was a good solution to the problem. The preliminary design in some cases was shown to a few customers, to get their feedback at an early stage. This was followed by detailed design and its review was documented and circulated to the concerned people for their suggestions. The document was refined, if necessary. In one firm, since the innovation discussed was for an evolving product, i.e., an improvement over the older version, therefore there was no preliminary design for it.

The detailed design review was also addressed as the critical design review which was conducted by engineering and Q.A. In all four responding firms, Q.A. was involved at the design stage. One firm used Computer Aided Software Engineering (CASE) tools for designing.

Prototype and Coding stage

A Prototype, as defined earlier, is the trial model of the final product that would be delivered to the customer. In software firms, after the prototype stage, the product

went for coding. At this stage, the functional codes were written and tested for the localized functional unit, which was addressed as unit testing. This was followed by integration and system testing, where all codes were put together and tested as one system. Testing has been considered to be a very crucial activity at this stage. In fact, a test plan was written to define the approach to test the product. Two firms reported using supporting software for testing. One respondent said that his firm was now trying to go immediately from detailed design to coding, i.e., there would be no prototype stage. This happened mostly when the product was evolving, for example in cases where only functionalities were added. However, for entirely new products, prototyping was felt necessary. In 3 out of 4 firms, demonstration of prototypes was made to the customers. If the customers became interested, then sometimes they would partially cofund the development. In most cases, the manufacturer retained the copyright. If the customer suggested certain changes which were either economical or paid for, then the changes were considered. Otherwise, suggestions were reserved for future versions of the product. Based on the results of the internal tests and customer feedbacks, all the firms reported that the prototype had to be redesigned. One firm called it "iterative prototyping".

In terms of formal reviews within the engineering department, there were the preliminary design review stage, detailed design review stage and a review after the prototype stage. However, informal review meetings within the engineering were held on a regular basis. In 3 out of 4 firms, Q.A. was involved at the prototype stage. One firm also had a peer review.

Pre-production stage

Pre-production stage started after the prototype stage. During this stage, the production department was required to acquire and build inventory of all materials. This stage involved copying software from master tapes on to diskettes.

In 2 out of the 4 firms, the customer was involved at the pre-production stage. One firm had a "Targeted Ship" program, where the product went into specific customers' hands prior to full scale production. These customers were selected as they had the capability to immediately test the product on site. Their feedback was awaited for only two weeks. If they reported a defect, the software was rectified. The suggested enhancements were not incorporated immediately but were reserved for future versions of the product.

Production stage

Production again involved copying the software from the master tapes onto the diskettes on a mass scale. Printing of the manuals has also been reported as part of the production activity in the software firms. 2 out of 4 firms reported contracting out the entire production.

Product launch stage

During this phase, firms brought the product to the market place. In 3 out of the 4 firms, the product was marketed right from the prototype stage, i.e., a few orders were procured at this stage only. Once a few orders were obtained then the firm moved to

mass production. Simultaneously, efforts were made by the sales department to obtain maximum number of orders. Again, exact details of the product launch activities could not be obtained because all the respondents were from the engineering department.

Based on the preceding description of the innovation process in the software firms, a chain linked model as shown in Figure VII was developed.

Figure VII

Conclusions for sections 5.1.1 and 5.1.2

This research study based on questions and probes developed in Appendix II helped in generating two models of the innovation process, one for the hardware firms and the other for software firms, which have been shown in Figure VI and Figure VII respectively. Further, on careful examination of the innovation process of the hardware and software firms, some differences between the two types of firms have also been noted. This section also highlights some other observations associated with the innovation process.

Surprisingly, not much has been mentioned in the literature regarding role of quality assurance (Q.A.) in the innovation process. This study found that Q.A. played a very significant role during the innovation process, both in the hardware and the software firms. The Q.A. department was reported to be active right from the designing phase and was said to be involved in almost all meetings and reviews.

The role of Q.A. varied from firm to firm. Some of the functions in both hardware and software firms were reported as follows:

- to ensure job quality, by checking the validity of the design, performing qualification test at the prototype stage, etc.
- to ensure clarity of information and proper documentation of all activities
- to work on the acceptance criteria, such as regulations the product has to pass and how the company intended to meet these criteria

- to ensure that the product conformed to the initial specifications
- to ensure that what was being promised to the customer was actually being built

All the documents were said to be signed by engineering, production and Q.A.

In two firms, Q.A. also had the power to veto a document.

These observations support the findings of Silva (1992), which suggest that Q.A. has to play a very active role throughout the innovation process to ensure a quality product is delivered on time to the customers.

Just as in the *a priori* model, marketing activities were reported to start upfront during the new product development process, both in the hardware and the software firms. 81% of hardware firms reported advance market planning, starting at the preliminary design stage. This demonstrates that hardware firms in the electronic and telecommunication industry are focusing their efforts on both engineering and marketing activities simultaneously. By adopting this procedure, these firms ensured that time to market is minimal, which is the key to survival in this industry. Exact detail of marketing activities at each stage could not be gathered because almost all the respondents were from engineering. However, standard activities as mentioned in many marketing text books, prior to full scale launching of the product were highlighted as follows:

Identifying the target customers for beta test and getting their commitments for field trials. In this way, the marketing department acted as an interface between customers and technical personnel. About detailed design stage, the marketing department was reported to start work on advertisement, promotions and technical information to be provided to

the customers through brochures etc. This was followed by planning of the distribution network. Further, recruitment and training of the new as well as the existing sales force was conducted prior to actual production of the product.

Two software firms reported advance marketing activities in terms of dealer network planning, advertising, promotion, etc. These advance marketing activities started just at the coding phase. It is inferred that since most of the customers were already using the firms' previous version of the software, very extensive market planning was not required to convince them to upgrade their software. However, once the product was manufactured, these firms always tried to increase their customer base.

It was also observed that project teams were not well defined in most of the hardware firms. Only 44% of the firms reported having formal project teams. Since a majority of the firms did not report having formal project teams, it therefore can be said that this observation is very company specific and is not generalizable across all the firms in the electronics and telecommunication industry. For 44% of these firms, once the product concept was approved, a project team was formed. This team usually comprised of people from the marketing, manufacturing, research & development and customer service departments. In most cases it was headed by a project director or a project manager. This organization of the team was reported to be quite dynamic, as people coming in during the early stages moved out and were replaced by new people as the product progressed. For example, once the product entered the field trial, the R&D involvement became minimal while the field trial group became heavily involved. The

project teams in most firms met every two weeks starting from the definition of the product to the end of the product. These meetings were reported to be formal and were documented. The minutes of meeting with action items and resolution of action items were also circulated. In one hardware firm, the project team met only at the completion of each of the five stages of the innovation process. In some firms, ad hoc special meetings were also reported, where the president called upon the project team members. The review at each stage by the project team members has been termed by some respondents as the "gating process".

Two software firms also reported having project teams. The project team comprised of members from product management group, engineering group and marketing group. This project team came up with a proposal and presented it to the owners of the firm. The function of the team was to evaluate which features suggested by the research group and customers to add, to set up a time scale and to work on costs and benefits.

On the basis of overall description of the innovation process in the software and hardware firms, noticeable differences observed between the two can be summarized as follows:

First, software firms, as compared to the hardware firms, focused less on the new product strategy stage. This suggests that the software market is very volatile and firms either have to respond very quickly to the changing demands of the market and therefore are unable to plan a product few years in advance or they do not have the expertise or resources to define their product and market few years in advance.

Second, the role of Q.A. was more predominant in the software industry as compared to the hardware industry. This is possible because the stages of the innovation process are not that elaborate in the software industry as compared to the hardware industry, therefore, Q.A. could play a much active role in the software industry.

Third, software firms did not have extensive marketing activities prior to product launch. Few activities started only after prototype testing as opposed to marketing activities starting at the designing stage in the hardware industry. The possible reasons could be, the software firms already had users of their product and it was not very costly for these users to install the updated versions. The hardware firms on the other hand, had to market much more expensive products to new customers which required extensive resource commitment and planning.

Fourth, production which was generally contracted out was reported as a very simple activity in the software industry. On the other hand, production was a very complex and detailed activity in the hardware firms and in most cases was performed in-house. Further, production was active in the upfront activities of the innovation process in 50% of the hardware firms. In software firms however production did not participate in any of the upfront activities. This was expected, considering the difference in nature of products manufactured by the two types of firms.

Fifth, interaction between marketing and R&D departments was observed only in 2 out of 4 software firms whereas 75% of the hardware firms reported a regular interaction between the marketing and R&D departments. This observation may be due to

differences in the organizational functioning, time pressure and the nature of products in the two type of firms.

5.2 Innovation Turnaround Time

The second objective of this research was to determine, in terms of relative importance, what strategies the firms in the electronic and telecommunication industry have adopted to reduce the innovation turnaround time. The analysis for this objective was quantitative and was performed with the help of the statistical package, SPSS/PC¹.

There were 34 variables identified from the literature being helpful in reducing the innovation turnaround time. The respondents were asked to rate the importance of these variables on a Five Point Itemized Rating Scale² with 1 representing not important and 5 representing very important. Respondents marked zero for not applicable.

Based on similarity, these 34 variables were grouped into 10 broad categories. For example, automation of design process, automation of manufacturing process, automation of testing process and automation of material handling are grouped together on the basis of automation of various processes during the new product development, hence the group is termed technological sophistication.

Following is the list of these categories:

I. Top management involvement

1. Itemized Rating Scales are non-comparative scales that force the rater to select one of a limited number of categories that are ordered in terms of their scale positions (Tull and Hawkins, 1976).

2. Further, according to Tull and Hawkins (1976), more homogeneous the population of interest, greater the need for four or more categories. Since it is easier to design and administer five to seven point scales as it is to administer two or three point scales, it is best to utilize at least five categories unless there is a specific reason not to do so.

2. Technological sophistication
3. Planning
4. Organizational dynamics.
5. Supplier relationship
6. Components manufacturing decisions
7. Quality of human resources
8. Budget and funds
9. Government policies
10. Marketing communications and launch efforts

Three types of statistical analysis were performed on the data. Section 5.2.1. deals with descriptive statistics for all variables, which includes frequency count/percentage, mean and standard error. Section 5.2.2, presents the correlation results among the variables for each of the 10 categories. Finally, Section 5.2.3. highlights the findings of factor analysis on these 10 categories.

Before presenting the results, it is necessary to mention that this is an exploratory study with a limited sample size which restricts the performance of very rigorous statistical analysis on the data collected. However, best efforts have been made to derive maximum meaning out of the data. Still, the results have to be treated with caution.

5.2.1 Descriptive Statistics

First of all, general observations are presented in the form of descriptive statistics. Descriptive statistics refers to analysis and synthesis of data so that a better description of the situation can be made and thereby promote a better understanding of the facts. One should note that it does not attempt to select the best alternative but only describes the choices that are open to the decision maker (Srivastava, Shenoy and Sharma, 1983). The descriptive statistics results are shown in the form of tables. Tables 5.1 to 5.10 present the summary of 1) percentage responses on the rating scale and 2) mean and standard error for each of the factors under the 10 categories. Table 5.11 presents the summary of all the variables considered important. Importance was established by performing t-test on each variable at significance levels of .01, .05 and .10.

Category 1: Top management involvement

The different roles of top management in the innovation process have been highlighted in the literature extensively. Table 5.1 presents the summary of the results of some of the ways in which top management can help to reduce the innovation turnaround time.

Table 5.1 - Percentage, Mean and Standard Error for Top ManagementInvolvement Related Variables

		% Responses							
		* Rating Scale							
No.	Top mgmt. involvement related variables	1	2	3	4	5	N.A.	Mean	S.E**
1.	Employee motivation	0.0	0.0	4.5	31.8	63.6	0.0	4.59	.126
2.	Feedback time	0.0	0.0	18.2	36.4	45.5	0.0	4.27	.164
3.	Accessibility	4.5	0.0	18.2	36.4	40.9	0.0	4.09	.217
4.	Delegation of decision making	0.0	0.0	22.7	50.0	27.3	0.0	4.05	.154
5.	Participation	9.1	13.6	31.8	31.8	9.1	4.5	3.19	.245

* 1 = Not Important, 2 = Not that Important, 3 = Moderately Important 4 = Important, 5 = Very Important, N.A = Not Applicable

** S.E = Standard Error

As can be seen from Table 5.1, employee motivation is perceived to be the most important factor under the top management involvement. 63.6% of the respondents felt that it is a very important factor helping to reduce the innovation turnaround time. The mean score of 4.59 indicates that on average, the respondents perceived employee motivation as key to expediting the innovation process. The employee motivation, as mentioned earlier, can be in the form of work recognition or appreciation, incentives/bonus, promotions, etc.

The other variables, mainly accessibility of the top management for discussing problems, delegation of decision making to lower organizational levels and feed-back time have also been considered as important in expediting the innovation process. This can be inferred, from the fact that mean scores for each of these factors is above 4, where 4 stands for important on a five point scale. However, top management participation has not been considered to be as important as the other four factors. In fact, two respondents pointed out that a regular involvement of top management was not good for reducing the innovation turnaround time of the projects in hand, as it generates more changes. However, they acknowledged that top management's advice may be useful for later versions of the same products.

Setting up arbitrary deadlines/milestones to create a sense of urgency of the project was another factor suggested by two respondents as affecting innovation time. One of them very aptly stated this as, "the result and the time frame to get the result must be very well understood".

Thus, based on the factors mentioned in the questionnaire and the comments of

the respondents, it can be concluded that top management foresight, interest, initiative and decision making has a great impact on the speed of execution of an innovation project.

Category 2: Technological sophistication

Technology, especially in terms of automation of the various stages involved in the new product development process, has been the focal issue in literature on increasing the speed of the innovation process. The summary of findings of this study regarding the importance of some of these strategies is shown in Table 5.2.

Table 5.2 - Percentage, Mean and Standard Error for Technological Sophistication Related

Variables

No.	Technology related variables	% Responses							
		* Rating Scale						Mean	S.E**
		1	2	3	4	5	N.A.		
1.	Testing process automation	0.0	4.5	22.7	45.5	27.3	0.0	3.96	.180
2.	Design process automation	9.1	0.0	36.4	18.2	36.4	0.0	3.73	.265
3.	Manufacturing process automation	0.0	13.6	27.3	27.3	22.7	9.1	3.66	.233
4.	Material handling automation	0.0	13.6	27.3	13.6	22.7	22.7	3.59	.272

* 1 = Not Important, 2 = Not that Important, 3 = Moderately Important, 4 = Important, 5 = Very Important, N.A = Not Applicable

** S.E = Standard Error

Automation of testing process emerged to be the most important factor in reducing the innovation turnaround time in the technology sophistication category. As can be seen from Table 5.2, 72.8% of the respondents (Mean 3.96) felt that it is either important or very important. This is quite logical since minimizing the defects at prototype stage can prevent costly and time consuming iterations at the manufacturing stage. One respondent specifically mentioned that automated testing capability is a great asset in innovation turnaround time reduction.

Automation of the design process was also rated as most important by 36.4% of the respondents. This is the highest rating amongst the four variables in this category. This indicates that firms give top priority to achieving an optimal and flawless design in order to minimize iterations at the later stages. It also cuts the design time. This finding is similar to the finding of Vesey (1991), who suggested that design engineers should be using computer-aided design systems to increase engineering productivity. Automation of manufacturing and material handling were rated as moderately important. No specific reason could be assigned for the observation that automation of manufacturing was rated as moderately important. Since material handling is one of the activities within production, it is therefore conceivable that respondents have rated this also as moderately important.

Selection of the appropriate off the shelf software packages for the engineering and manufacturing stages was also suggested by respondents as an important factor in expediting the innovation process. Examples cited were that for Very Large Scale Integration (V.L.S.I) packages and Application Specific Integrated Circuit (A.S.I.C)

packages. One respondent also suggested that firms should have an aggressive approach to introduce new tools, i.e., have an "adaptation will", for new technologies. Vesey (1991) has also made a similar suggestion, which supports the findings of this study. According to him, firms should adopt technology that gives people the most current, proven tools to perform their jobs.

Category 3: Planning

Planning the new product development process in a way that is conducive for its expedition depends on certain factors. Five such factors were identified from literature as helping to reduce the turnaround time. As can be seen from Table 5.3, three of the factors have been given almost the same high rating by the respondents. These were R&D and marketing department meetings, design and manufacturing department meetings and having regular formal check-points throughout the innovation process.

Table 5.3 - Percentage, Mean and Standard Error for Planning Related Variables

No.	Planning related variables	% Responses						Mean	S.E**
		* Rating Scale							
		1	2	3	4	5	N.A		
1.	R&D and marketing meetings	0.0	13.6	13.6	36.4	36.4	0.0	3.96	.223
2.	Design and mfg. meetings	4.5	0.0	13.6	50.7	22.7	9.1	3.95	.211
3.	Formal checks	9.1	4.5	9.1	40.9	36.4	0.0	3.91	.262
4.	Pre-planned job allocation	9.1	9.1	13.6	45.5	22.7	0.0	3.64	.259
5.	Design, mfg. and marketing meetings	9.1	9.1	18.2	36.4	18.2	9.1	3.50	.276

* 1 = Not Important 2 = Not that Important, 3 = Moderately Important, 4 = Important, 5 = Very Important, N.A = Not Applicable

** S.E = Standard Error

These factors have been rated as either important or very important by 70 to 75% of the respondents. The mean value for these factors is also high, ranging between 3.91 and 3.96. Again, these findings are in accord with the literature, which lays a heavy emphasis on interaction between all the concerned departments upfront, in order to thrash out matters in advance to ensure the future smooth flow of the innovation process. Meetings between the R&D and marketing departments at the initial stages of concept formation can help to increase the market acceptability of the product. Similarly, meetings between the designing team and the manufacturing team can help to ensure convenient product manufacturability. Having formal check-points at the end of each stage also ensures that before proceeding to the next stage, all the issues related to the previous stage have been reviewed and documented.

Pre-planned job allocation and meetings between the designing, manufacturing and marketing departments have been rated as moderately important. One respondent felt that the marketing department should not be allowed to change specifications very frequently. Another suggestion from a respondent of a software firm was that unlike pre-planned job allocation, flexibility of tasks was more important in the software industry in order to reduce the innovation turnaround time.

Some other important suggestions by the respondents pertaining to the role of planning in reducing the turnaround time are as follows:

- Systematic record keeping to avoid rehashing old or forgotten decisions.
- Keeping the lower staff apprised of the progress of the new product development. This makes them feel involved and hence motivate them to put in

their best effort.

- Adequate allocation of Quality Assurance resources or establishment of an effective quality system. It is felt that close monitoring of the innovation process right from the beginning helps to reduce errors and make the team more committed to standards set in the beginning.

Category 4: Organizational dynamics

Working style or practices adopted in the organization also has an impact on the speed of the innovation process. Five practices were identified from literature as helping to reduce the innovation turnaround time. Table 5.4 presents the summary of the results of the respondents views on these practices.

Table 5.4 - Percentage, Mean and Standard Error for Organizational Dynamics Related**Variables**

No.	Organizational dynamics variables	% Responses								
		* Rating Scale						N.A.	Mean	S.E**
		1	2	3	4	5				
1.	Dedicating full-time tech. persons	0.0	0.0	13.6	31.8	54.5	0.0	4.41	.157	
2.	Parallel processing	0.0	4.5	27.3	45.5	22.7	0.0	3.86	.178	
3.	Forming cross- functional teams	9.1	9.1	18.2	40.9	22.7	0.0	3.59	.260	
4.	Interaction with customers	9.1	9.1	13.6	45.5	13.6	9.1	3.50	.267	
5.	Personnel orientation	9.1	13.6	22.7	36.4	18.2	0.0	3.41	.260	

* 1 = Not Important, 2 = Not that Important, 3 = Moderately Important, 4 = Important, 5 = Very Important, N.A = Not Applicable

** S.E = Standard Error

Table 5.4 clearly demonstrates that dedicating full time technical personnel to the new product development process is the most important factor in the category of Organizational Dynamics. 86.3% of the managers felt it to be important or very important. The mean of 4.4 substantiates this. This finding is also consistent with the findings of Kumar and Kumar (1991). Surprisingly, the formation of cross functional teams and parallel processing have not emerged to be the most important factors, even though literature gives the impression that it is a crucial factor. The means for these factors are between 3.6 and 4.0, which indicates that respondents consider these factors to tend towards important only. The other factors, namely, personnel orientation and interaction with customers have been rated by the majority of the respondents as more towards moderately important. In fact, one of the respondents has specifically mentioned that there should not be a regular interaction with the customers during the development process as they would keep suggesting changes which would go against expediting the innovation process. Regarding personnel orientation, one of the respondents made an observation that designers with past experience in manufacturing can also help in reducing the turnaround time of the innovation process. This is indeed true as these designers would be in a better position to consider the manufacturability aspect of the innovation process and hence save time in terms of the iteration of the design process.

Category 5: Supplier relationships

The effect of supplier-firm relationship on the speed of the innovation process has also been highlighted in the literature. As can be seen from Table 5.5, none of the two

factors in this category emerged to be of striking importance. Surprisingly, meetings between the supplier and the manufacturing firm are not even considered moderately important. This is quite in contrast to the Japanese system, where the suppliers are considered to be an integral part of the whole innovation process and their participation is said to help increase the speed of the innovation process (Takeuchi and Nonaka, 1984).

Table 5.5 - Percentage, Mean and Standard Error for Supplier Related Variables

		% Responses								
No.	Supplier related variables	* Rating Scale						Mean	S.E**	
		1	2	3	4	5	N.A.			
1.	Early involvement of suppliers	0.0	9.1	22.7	22.7	31.8	13.6	3.90	.241	
2.	Supplier and manufacturer meetings	4.5	27.3	27.3	22.7	4.5	13.6	2.95	.235	

* 1 = Not Important, 2 = Not that Important, 3 = Moderately Important, 4 = Important, 5 = Very Important, N.A = Not Applicable

** S.E = Standard Error

Category 6: Components manufacturing decisions

As can be seen from Table 5.6, the trade-off between internal and external production, i.e., producing only critical components internally and buying other components from outside vendors has been considered as important or very important by only 50% of the respondents. The mean of 3.62 suggests that on average, the respondents have an inclination to consider this factor as important.

Another important point cited by a respondent was on the issue of the trade-off between buying or leasing of equipment. The respondent felt that it is easier to take sanctions from the top management for leasing the equipment, because top management does not mind paying small instalments, as compared to paying lump-sum amount for new equipment.

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PM-1 3 1/2" x 4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

Table 5.6 - Percentage, Mean and Standard Error for Components Manufacturing Related Variable

No.	Components manufacturing related variable	% Responses						Mean	S.E**
		* Rating Scale					N.A.		
		1	2	3	4	5			
1.	Trade-off between internal and external production	0.0	13.6	31.8	27.3	22.7	4.5	3.62	.223

* 1 = Not Important, 2 = Not that Important, 3 = Moderately Important, 4 = Important, 5 = Very Important, N.A = Not Applicable

** S.E = Standard Error

Category 7: Quality of human resources

The type of employees involved in new product development has a significant impact on the speed of the innovation process. Table 5.7 clearly demonstrates how important the respondents perceived the quality of human resources to be in terms of reducing the innovation turnaround time.

Table 5.7 - Percentage, Mean and Standard Error for Human Resource Related Variables

		% Responses							
No.	Human resource related variables	* Rating Scale						Mean	S.E**
		1	2	3	4	5	N.A.		
1.	Availability of diverse technical personnel	0.0	0.0	0.0	36.4	63.6	0.0	4.64	.105
2.	Employee problem solving capability	0.0	0.0	9.1	18.2	72.7	0.0	4.64	.140
3.	Past experience of employees in new product development	0.0	9.1	27.3	22.7	40.9	0.0	3.96	.223
4.	Flexibility of employee technical skills	4.5	9.1	22.7	31.8	31.8	0.0	3.77	.246

* 1 = Not Important, 2 = Not that Important, 3 = Moderately Important, 4 = Important, 5 = Very Important, N.A = Not Applicable

** S.E = Standard Error

The availability of diverse, technically-qualified personnel is considered to be the most important factor by maximum number of respondents in this category. It is also considered to be the most important (Mean 4.64) variable among all the variables considered for expediting the innovation process. 100% of the respondents considered it to be either important or very important. This demonstrates that a firm's greatest asset is to possess in-house employees with different technical skills, which can be pooled effectively during the innovation process. Employee problem-solving capability was also rated as very important by almost all the respondents. However, these observations suggest that the very nature of the questions must have forced the respondents to give these two variables a high rating. Flexibility of employees' technical skills and past experience of employees in new product development have also been rated as important in expediting the innovation process. In fact, this observation can be substantiated by considering Toyota's system in Japan, which requires its workers to master a variety of tasks in order to expedite the production process. The American system, on the other hand, is based on narrowly defined tasks which go against the expedition of the production process (Larson, 1992).⁹ Thus, it can be said that the turnaround time of the innovation process is highly dependent on the quality of human resources in a particular firm. One of the respondents aptly suggested that not only are the skills of individuals important, but also the teamwork between project staff is very essential. This is again a requirement at Toyota systems (Larson, 1992).

⁹ The Ottawa Citizen, September 26, 1992.

Category 8: Budget and funds

From Table 5.8, it can be seen that the availability of sufficient funds was considered either important or very important by approximately 82% of the respondents. This finding is again in congruence with the findings of Kumar and Kumar (1991). One respondent specifically mentioned that the ready availability of funds was critical for expediting the innovation process as insufficient funds would result in less functionality and cause unnecessary delays. However, one respondent gave a different opinion. He felt that if a firm has limited resources, then the employees try to think of simpler and faster methods to do a specific task. But he acknowledged this was more applicable for small projects.

A decentralised budget was considered to be moderately important. However, one respondent rated decentralized budgets to be very important because he felt balancing of resources was very critical, as giving too much to one department and depriving the other departments of funds would not help in achieving inter-departmental harmony, and this, in turn, would have a negative impact on the speed of the innovation process.

Table 5.8 - Percentage, Mean, Standard Error for Budget and Funds Related Variables

No.	Budget and funds related factors	% Responses						Mean	S.E**
		* Rating Scale							
		1	2	3	4	5	N.A.		
1.	Availability of sufficient funds	0.0	0.0	13.6	31.8	50.0	4.5	4.38	.161
2.	Decentralized budget	0.0	9.1	45.5	13.6	18.2	13.6	3.47	.221

* 1 = Not Important, 2 = Not that Important, 3 = Moderately Important, 4 = Important, 5 = Very Important, N.A = Not Applicable

** S.E = Standard Error

Category 9: Government policies

One of the external factors influencing the speed of the innovation process is the government's approach to dealing with organizations involved in manufacturing activities. Table 5.9 gives an idea as to what expectations the respondents have from government on different issues.

Table 5.9 - Percentage, Mean and Standard Error for Government Policies Related Variables

No.	Government policies related variables	% Responses						Mean	S.E**
		* Rating Scale							
		1	2	3	4	5	N.A.		
1.	Less bureaucracy	4.5	4.5	27.3	22.7	18.2	22.7	3.59	.272
2.	Extending financial support	9.1	13.6	13.6	36.4	18.2	9.1	3.45	.285
3.	Assistance from technical bodies	22.7	18.2	27.3	0.0	13.6	18.2	2.56	.326

* 1 = Not Important, 2 = Not that Important, 3 = Moderately Important, 4 = Important, 5 = Very Important, N.A = Not Applicable

** S.E = Standard Error

It can be seen from the above table that a majority of the respondents (54.6%) rate monetary support from the government as important in the expedition of the innovation process. This monetary support can be in terms of loans at low interest rates for buying critical capital equipment, etc. On average, reducing bureaucracy to reduce the innovation turnaround time has been considered to be between moderately important and important. One respondent felt that their firm could expedite the innovation process for its products, as some tests which it is contractually obliged to farm out to a government approved organization can be done in-house on a practical basis.

Assistance from technical bodies, has been, on average, felt to be not so important. This gives an impression that either there are not enough government technical bodies so that the respondents could express their opinion on this subject or that their firms have good internal resources to solve their problems.

The need for an industrial consortium between the firms was emphasized by one of the respondents.

Category 10: Marketing communication and launch efforts

From Table 5.10, it can be seen that the training of the sales force is considered to be important by a majority of the respondents. This is true because in industrial markets, a properly trained and motivated sales force plays a very significant role in increasing the market acceptability of the product. The extent of the distribution network has also been considered important. Again, making a product quickly available to the user can help ensure a faster completion of the innovation process. The frequency of

advertising has, on an average been considered to be not so important. This is again logical as most of the firms were selling to industrial customers and the literature suggests that industrial marketer's promotional mix emphasizes personal selling rather than advertising (TV, newspaper) to reach potential buyers (pp.8-9, Hutt and Speh, 1981)

Table 5.10 - Percentage, Mean and Standard Error for Marketing Communications and Launch Effort Related Variables

No.	Marketing related variables	% Responses						Mean	S.E**
		* Rating Scale							
		1	2	3	4	5	N.A.		
1.	Sales-force training	0.0	9.1	9.1	40.9	36.4	4.5	4.10	.206
2.	Extent of distribution	4.5	9.1	18.2	40.9	22.7	4.5	3.71	.240
3.	Frequency of advertisements	9.1	18.2	50.0	9.1	4.5	9.1	2.80	.213

* 1 = Not Important, 2 = Not that important, 3 = Moderately Important, 4 = Important, 5 = Very Important, N.A = Not Applicable

** S.E = Standard Error

Some other factors considered to be important by the respondents in reducing the innovation turnaround time are as follows:

- Youth in the firm, as young people are more energetic and supposedly have new ideas.
- Small size of the firm, as this helps to reduce the bureaucracy

In summary, the descriptive statistics related to each strategy gave an overall picture as to how the respondents perceived these strategies in terms of their importance in reducing the innovation turnaround time.

Table 5.11 presents in terms of relative importance, the list of all the variables considered statistically significant at significance levels of .01, .05 and .10 respectively for expediting the innovation process.

Statistical importance was determined by performing single tailed t-test¹⁰ on each variable having a mean over 3.0.

¹⁰ t-test was performed to determine whether the variable means over 3 on the rating scale were important or not; 3 represents the centre point on the 5 point scale.

Table 5.11 - Summary of Variables Considered Important for Reducing the Innovation Turnaround Time

No.	Variables	Mean
1	Availability of diverse technical personnel	4.64***
2	Employee problem solving capability	4.64***
3	Employee motivation	4.59***
4	Dedicating full-time technical persons	4.41***
5	Availability of sufficient funds	4.38***
6	Top management's feedback time	4.27***
7	Sales-force training	4.10***
8	Accessibility of top management	4.09***
9	Delegation of decision making	4.05***
10	Past experience of employees in new product development	3.96***
11	R&D and marketing meetings	3.96***
12	Testing process automation	3.96***
13	Designing and manufacturing meetings	3.95***
14	Formal checks	3.91***
15	Early involvement of suppliers	3.90***
16	Parallel processing	3.86***
17	Flexibility of employee technical skills	3.77***
18	Design process automation	3.73***
19	Extent of distribution network	3.71***
20	Manufacturing process automation	3.66***
21	Pre-planned job allocation	3.64**
22	Trade-off between internal and external production	3.62***
23	Material handling automation	3.59**
24	Forming cross-functional teams	3.59**
25	Less government bureaucracy	3.59**
26	Interaction with customers	3.50**
27	Design, manufacturing and marketing department meetings	3.50**
28	Decentralized budget	3.47**
29	Government's financial support	3.45*
30	Personnel orientation	3.41*

*** Significantly different from 3 at the .01 probability level

** Significantly different from 3 at the .05 probability level

* Significantly different from 3 at the .10 probability level

5.2.2 Correlation Analysis

The variables identified in the preceding analysis were arbitrarily grouped into ten categories based on both intuition and existing literature. However, in order to statistically determine the strength of relationship among the variables within each category, a correlation analysis was performed.

Correlation is a technique used to determine to what degree one variable is related to another (Srivastava, Shenoy and Sharma, 1983). The analysis was done by using SPSS/PC+.

Thus the results of the correlation analysis would not only demonstrate the strength of relationship among the variables but also show whether they are positively correlated or negatively correlated. The variables strongly correlated would indicate that they are viewed by the respondents in the same light. This in turn would enable us to modify the questionnaire for future research.

The correlation results for the variables found to be correlated at a significance level of .01 and .001 within each category are presented in Table 5.12 as follows:

Table 5.12 - Correlation Results

No.	Correlated Variables	Correlation coefficient
Technology sophistication category		
1.	Automation of manufacturing process and automation of testing process	.72**
2.	Automation of manufacturing process and automation of material handling process	.69*
3.	Automation of material handling and automation of testing process	.78**
Planning category		
4.	R&D & marketing department meetings and designing & manufacturing department meetings	.66**
5.	R&D & marketing department meetings and designing, manufacturing & marketing department meetings	.60*
6.	Designing & manufacturing department and designing, manufacturing & marketing department meetings	.79**
Marketing category		
7.	Training of sales force and frequency of advertisements	.54*
8.	Training of sales force and extent of distribution	.53**

* Level of significance = .01

** Level of significance = .001

As can be seen from Table 5.12, under the technological sophistication category, the automation of the manufacturing process and the automation of the testing process are significantly correlated. Since testing is performed within the manufacturing department, therefore automation of testing can be considered as a subset of automation of manufacturing. Further, automation of the manufacturing process and automation of the material handling process are also shown to be significantly correlated. This is also possible because material handling, as suggested in the literature, is an integral part of manufacturing. Thus, it could also be a subset of automation of manufacturing variable rather than being a separate variable. Hence, for future research, the questionnaire can be modified as follows: automation of manufacturing can have automation of material handling and automation of testing process as its subset. This would help in having more distinct variables within the technological sophistication category.

Table 5.12 also demonstrates that there is a significant correlation between R&D and marketing department meetings and designing and manufacturing department meetings. Similarly, there is a significant correlation between designing & manufacturing department meetings and designing, manufacturing and marketing department meetings. This observation presents a picture that the respondents are considering the meetings aspect as one variable. It also suggests that they prefer interaction. Based on the responses, it is also felt that instead of having one question on meeting between designing, manufacturing and marketing department, there should have been two separate questions. The first question should have been on meetings between the designing and marketing departments and the second question should have been on meetings between

manufacturing and marketing departments.

In remainder of the categories, namely; management involvement, organizational dynamics, supplier relationship, component manufacturing decision, human resources, budget & funds and government support, though the variables shared covariance but they were not significantly correlated. However, under the marketing communication and launch efforts, training of the sales force has been significantly correlated with the extent of the distribution network and the frequency of advertising. No concrete inference could be drawn from this result.

Thus, running a correlation analysis has helped in identifying a few significant inter-relationships between the independent variables in each category. It has also helped in making suggestions for possible refinement of the research instrument for future research.

5.2.3 Factor Analysis

After performing the correlation analysis on the variables in each category, the next step was to determine how the respondents were categorizing their responses, i.e., whether they perceived these 10 categories as distinct groups or on some other basis, they were grouping these as well. Therefore, factor analysis technique was used to determine the underlying construct for the variables considered important in reducing the innovation turnaround time.

Factor Analysis is a statistical technique used for identifying a relatively small number of factors that can be used to represent relationships among sets of many interrelated variables. It thus helps to identify constructs or factors assumed to underlie the observed variables (SPSS/PC+ Statistics™4.0). To run factor analysis, the sample size should be greater than the number of variables. Therefore, for a sample size of 22, factor analysis was run with the predetermined 10 categories instead of using 34 variables. Kaiser-Meyer-Olkin (KMO) test was performed to ensure whether to proceed with factor analysis for such a small sample size or not. This measure is an index for comparing the magnitudes of the observed correlation coefficients to the magnitudes of partial coefficients. According to this test, a KMO value less than 0.5 is an indication that factor analysis will not be of any significance (SPSS/PC+ Statistics™ 4.0). In this analysis, KMO was found to be approximately 0.4. Since it has been acknowledged earlier that this is an exploratory study with limited sample size which restricts rigorous statistical analysis, therefore it was decided to go ahead with factor analysis and see whether the results were interpretable or not.

Under Factor Analysis, Varimax Rotation was used. This attempts to minimize the number of variables that have high loadings on a factor. Essentially, rotation reallocates the loadings. Thus, the first rotated factor no longer necessarily account for the maximum amount of variance. The amount of variance accounted for by each factor has to be recalculated (Stevens, 1986). This enhances the interpretability of the factors.

Principal Component analysis extracted 4 factors. For the purpose of this analysis, the rotated factor matrix was considered. The factor loadings produced by the analysis are shown in Table 5.13. The loadings represent the contribution made by the variables towards defining the factor.

These groupings give an insight as to how the respondents tend to think when they marked their responses.

The first factor has an underlying dimension of **project management** where planning aspect of the new product development has been coupled with the organizational dynamics and the quality of human resources. This is very logical because to manage the project, first of all organizational practices should be such that they foster speedy execution of the project. Further, the participants in the process should have flexible skills and past experience in the new product development process. All this helps in better planning, which in turn results in expediting the innovation process.

The second factor has the underlying construct of **external influence** on the innovation process. This factor includes two variables, namely; the government policies and the supplier relationship, which are indeed the external sources influencing the speed of the innovation process. The negative loading of the supplier relationship suggests that

respondents prioritize their options when considering the influence of external variables on the speed of the innovation process. If they focus on supplier relationships then they give less importance to the government policies and vice-versa.

The third factor is not a very distinct factor. However, it can be interpreted as having the underlying construct of **direct product related issues**. It groups together technological sophistication and marketing communications and launch efforts. This shows that the respondents are considering these two variables to be directly product related issues, where technological sophistication is the input to faster production of a better product and marketing communications & launch efforts is responsible for quicker acceptability of this product in the market.

The fourth factor has the underlying construct of **top management commitment**. Top management involvement, and budget and funds both belong to this factor, which is again quite logical, because it is the top management which sanctions the budget or makes available the funds for execution of the new product development process. Essentially, top management participation is in terms of their policies and granting of funds in order to expedite the innovation process.

Table 5.13 - Factor Loadings for 10 Broad Categories Helping in Turnaround Time Reduction

No.	Innovation turnaround time reduction	Factor 1	Factor 2	Factor 3	Factor 4
1	Management involvement				.85
2	Technology sophistication			.78	
3	Planning	.89			
4	Organizational dynamics	.71			
5	Supplier relationship		-.67		
6	Component manufacturing decisions*				
7	Human resources	.75			
8	Budget and funds				.63
9	Government policies		.85		
10	Marketing and launch efforts			.68	

* Factor loading for "component manufacturing decision" has not been shown in this table, as factor loadings only over .6 have been considered by using the "Sort" command in SPSS/PC+. This figure was chosen because Comrey (1973) has suggested that loadings in excess of .63 are considered very good for data analysis. Further, he has stated, choice of the cutoffs of size of loading to be interpreted is a matter of researcher preference.

From the researcher's viewpoint, it is felt that the four factors obtained empirically could have been better grouped as follows: the first factor could have also included marketing and launch efforts, which has empirically been grouped with technological sophistication. This would therefore link all the categories concerned with the execution of the innovation process involving middle management level activities and the factor could be still termed as **project management**. The external influence factor and the top management commitment factor as determined empirically could remain the same. However, the third factor could be the **technology** factor which would include only technology sophistication. Table 5.14 presents the summary of the above mentioned discussion.

Table 5.14 - Comparison of Factors Determined Empirically and Factors Considered**Logical from Researcher's View-point**

Comparison	Factor 1	Factor 2	Factor 3	Factor 4
Empirical by factor analysis	Planning Organizational dynamics Human- resources	Supplier relationship Government policies	Technology sophistication Marketing & launch effort	Management involvement Budget & funds
Researcher's view-point	Planning Organizational dynamics Human- resources Marketing and launch effort	Supplier relationship Government policies	Technology sophistication	Management involvement Budget and funds

Thus, overall, Factor Analysis has helped to draw reasonable inference about the constructs which underlie the observed variables. These four factors¹¹ provided a deeper insight into the perceptions of respondents about the strategies considered important for expediting the innovation process.

¹¹ Since four factors in the case of ten categories seemed to be high in number, an attempt was made to see the results by restricting the number of factors to three. However, no coherent interpretation could be given to the factors.

6. CONCLUSIONS

In this section, conclusions of the study will be presented, followed by the limitations, benefits and implications of the study.

This study found that most firms in the Canadian electronic and telecommunication industry impose some sort of conceptual order on the innovation process, as was also determined by Kline (1986) in the case of American firms. These firms were also aware that in this competitive and rapidly changing business environment, expediting the innovation process is the key to survival.

All but one respondent described the innovation process as a chain linked process. Departments such as marketing, manufacturing and Q.A. were reported to be involved upfront, in order to streamline the innovation process and to ensure that the products did not go through several rounds of iterations in the future. These firms felt that it was worth putting in more effort in the beginning in order to avoid more time-consuming and costly iterations. These efforts involved holding many intra-departmental and inter-departmental reviews at each stage of the innovation process. This demonstrates that the firms are also promoting horizontal communication along with traditional vertical communication. 44% of the hardware firms also indicated that they had defined a strategic role for the new product before designing it. This gives an indication that hardware firms are realizing the need to do a formal analysis of the role of new products to assess their impact on the firm's present and future business. Another interesting finding was that a majority of the hardware and software firms reported that quality assurance (Q.A.) plays a significant role throughout the innovation process. The role of

Q.A. was described to ensure clarity of information and proper documentation of all activities linked to the innovation process. They also checked the validity of the design, performed qualification test at the prototype stage, etc. This clearly demonstrates that in the face of intense competition, the firms in the electronic and telecommunication industry are taking all the precautions to minimize the number of iterations in the product design. By minimizing iterations, these firms gain competitive advantage as they reduce their cost of operations and also reduce time to reach the market.

Some differences between the hardware and the software firms' innovation patterns were also observed. Compared to software firms, more hardware firms reported working on the strategic role of the product and scheduling advance marketing activities. Further, the production activities were much more complex in the hardware firms as compared to the software firms due to the difference in the nature of the products produced by them. Since the activities were complex in the hardware firms, therefore the production department was reported to be involved upfront, unlike in software firms, where production was involved at the end of the innovation process.

To reduce the innovation turnaround time, the following factors were considered important by a majority of the respondents:

- Top management issues related such as their accessibility, feedback time and delegation of decision making,
- Technological sophistication related such as automation of design process, automation of the manufacturing process and automation of the testing process.
- Planning related such as meetings between R&D and marketing, meetings

between designing and manufacturing and having formal check points after each stage of the innovation process.

- Organizational dynamics related such as dedicating full time technical persons on the project and parallel processing of activities.
- Supplier related such as involvement of suppliers early during the innovation process.
- Component manufacturing related such as trade-off between internal and external production.
- Human resources related such as availability of diverse technical people, employee problem solving capability, employee motivation and past experience of employees in decision making.
- Budget and fund related such as availability of sufficient funds for a project.
- product launch related such as sales force training.

The results of correlation analysis on the variables considered to help expedite the innovation process suggested certain modifications to the existing questionnaire. For example, the automation of the manufacturing process and automation of material handling were reported to be highly correlated. This being true, it is suggested that instead of considering automation of material handling as an independent variable, it could be treated as a subset of the automation of manufacturing variable.

Further, factor analysis generated four factors responsible for reducing the innovation turnaround time, namely; project management, external influence, direct product- related issues and management commitment. This provided an insight into the

underlying construct for the respondents' perceptions towards the factors influencing the innovation process.

Limitations

This study provides a limited basis for generalization as only 22 firms could be considered. Even though the firm selection criteria for having uniformity in the data limited the sample size, but still it provided a stronger ground for generalization.

Further, the small sample size restricted the scope for conducting a very rigorous statistical analysis. Therefore, statistical results of this study have to be treated with caution.

Since most respondents were from engineering departments, very limited information about marketing activities could be gathered. A natural extension of this research would be gathering views of marketing managers, as well to remove the bias.

Benefits and Implications

Although it is not an exhaustive study, it still provides a good foundation for future detailed research in the area of innovation, which has been scantily explored in the Canadian context. The information gathered in this study provides a detailed account of both the innovation process and the strategies used to reduce the innovation turnaround time in the electronic and telecommunication industry. Therefore this information can be used for conducting research in other industries as well. Further, a comprehensive list of factors considered important in expediting the innovation process, based on the literature

and suggestions made by the practising managers, will provide a good guideline to both new and not so successful firms in the industry in their efforts to expedite their innovation process. Thus, this research study will not only help in obtaining an overview of the innovation process but, based on the results of this study, firms might be able to restructure their activities and policies in order to gain competitive advantage.

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APPENDIX I: EXPLANATION OF FEEDBACK LOOPS SHOWN IN FIGURE III

KLINE'S CHAIN LINKED MODEL FEEDBACK LOOPS (Brief explanation of Figure III)

Feedback I

Thin arrows (f) indicates the work required to make changes in the prior stages along the Central Chain of Innovation (CCOI), depending on the deficiencies discovered in the service of the product. Thin circles represent constant interaction between the consecutive stages of the innovation process.

Feedback II

Heavy arrow (F) leading back to market finding indicates assessment of product utility and competitiveness that inevitably is part of the planning and design of later models or new systems for a given purpose.

Feedback III

Interaction between Research (R), Knowledge (K) and different stages along the CCOI is shown by the input and output arrows.

Feedback IV

The two way arrow marked "C". indicates that not only the long range science creates opportunities for new products, but also the perceived needs, or possible market advantages, can stimulate important researches.

Feedback V

Arrow "I" represents the direct connection between market and long range research.

Feedback VI

Arrow marked "S" explains that important link also exists between market products and research as the production of new instruments, tools, and processes has in many cases made possible new forms of research, thus explaining the dependence of research on technology output.

APPENDIX II: REQUEST LETTER GIVEN TO RESPONDENTS PRIOR TO THE INTERVIEW

Attn:

Dear Sir or Madam

Re: Research on the innovation process

Mr. Sandeep Mathur, one of our graduate students, is conducting a research study on the innovation process in the Canadian electronic and telecommunication industry in fulfilment of his master's thesis requirement under my supervision. This study has two objectives: the first is to understand and analyze the innovation process; the second objective is to generate a comprehensive list of strategies considered important to reduce the innovation turnaround time. As your firm is one of the leading innovating firms, your participation in this study would be greatly appreciated.

We will be asking you for an interview which will last no more than one hour. This session will include open ended questions where you will be asked to describe the innovation process for one of the recent products (last 2-3 years) for which you were responsible. This product should have been in the market for at least 6 months. Further, in order to have a comprehensive list of strategies considered important for expediting the innovation process, you will be asked to complete a questionnaire after the interview session. The questionnaire takes approximately fifteen minutes to complete.

All interview responses will be kept confidential. If desired, a summary report will be made available.

I appreciate your assistance as your help is essential to conduct this study.

Yours Sincerely,
Vinod Kumar, Ph.D., P.Eng
Graduate Supervisor
School of Business

APPENDIX III: QUESTIONNAIRE FOR THE TWO RESEARCH OBJECTIVES

- A:** Questionnaire containing open ended questions for the first research objective, along with the probes used by the researcher. This questionnaire remained with the researcher.
- B:** Self-administered questionnaire for the second objective given to the respondents to mark their responses

A:

Questions:

Conventions used in this interview schedule are:

- i Questions to be asked by the interviewer are in Lower Case
- ii Probes are in Lower Case, are in Bold and have been put in Parenthesis
- iii Interviewer notes are in Upper Case

Q-1 The firm -----

Q-2 Respondent name -----

Q-3 Respondent designation -----

Q-4 Division of firm -----

Q-5 Many firms follow a series of steps during innovation process (new product development process)
 Could you please describe the innovation process/new product development process (starting from either market research or basic/applied research to the final market introduction) for a product introduced within last 2-3 years which you were responsible for? (**what kind of decisions, major events were involved**). Further, this product should either be entirely new or should be a significantly modified/improved product over the previous/existing product, which the firm thinks is new for it. This product should have been in the market place for at least 6 months.

WILL MAKE CLEAR THAT THE WORDS INNOVATION PROCESS AND NEW PRODUCT DEVELOPMENT PROCESS ARE BEING USED SYNONYMOUSLY

PROBES FOR THIS OPEN-ENDED QUESTION

(a What was the starting phase of the innovation process, was it market research or basic/applied research or both

THIS WOULD ALSO INDICATE WHETHER IT IS TECHNOLOGY PUSH OR MARKET PULL PRODUCT INNOVATION OR BOTH

- b Did you have any stage where strategic role for the new product was determined? NEW PRODUCT STRATEGY STAGE**

THE FOLLOWING STAGES ARE INVOLVED IN MOST OF THE INNOVATION PROCESSES. HOWEVER IF THEY ARE BEING MISSED BY THE RESPONDENT THEN THEY WOULD BE SPECIFICALLY MENTIONED TO THEM AS A REMINDER.

- c Synthetic design (i.e., reduction to paper (drawings) of the specific features of a real embodiment of a real machine, system or device)**
- d Detailed design and Prototype development and testing**
- e Redesign and Production (Development Stage)**
- f Distribute and market]**

IT WILL ALSO BE DETERMINED WHETHER THERE IS ANY OTHER STAGE MENTIONED BY THE RESPONDENT DURING THE COURSE OF THE INTERVIEW WHICH HAS NOT BEEN INCLUDED IN THIS LIST SO THAT MORE DETAILS CAN BE ASKED.

FURTHER TO DETERMINE WHETHER A SEQUENTIAL OR A CHAIN LINKED APPROACH IS ADOPTED FOR THE INNOVATION PROCESS, FOLLOWING QUESTIONS WOULD BE ASKED:

- Q-6 Many firms have an inter-departmental interaction during the innovation process Which departments in your firm had feedback mechanism or a regular interaction and was this interaction formal or informal?**

PROBES TO BE USED

[Please tell us whether the interaction between the concerned departments was in terms of regular meetings which were held either weekly/ bi-weekly or monthly. If no such formal meetings were held, then what was the mode of interaction?

Were the minutes of the meeting kept?

Who was the incharge for holding these meetings?

Were these information type meetings or decision oriented meetings?

Based on above mentioned details for the meetings, please elaborate on the interaction between the following departments:

- a Designing and Manufacturing**
- b Designing, Manufacturing and Marketing**
- c Marketing and R&D**

- d Marketing and individual departments (depending on product deficiency or customer feedbacks)**
- e At what stages were the customers directly involved?**
- f Besides the above mentioned departments, were there any other departments participating regularly during the innovation process? }**

Thank you very much for your time for the interview. Now I will be asking you to fill a questionnaire, which will take you approximately 15 minutes.

B:

Listed below are a number of factors which would help in reducing the time taken for the innovation process (beginning from market finding or technology (basic/applied) research to product launch.

Please rate the importance of each of these factors for reducing the time taken for the innovation process/new product development process. **You are requested not to link these factors with criteria for success of product innovation.**

0 means not applicable
1 means not important
5 means very important

I Top management involvement

a Participation of top management through out the innovation process such as by holding weekly/monthly review meetings etc.	0	1	2	3	4	5
b Accessibility of top management and senior managers for discussing problems etc.	0	1	2	3	4	5
c Delegation of decision making to lower organizational levels	0	1	2	3	4	5
d Employee motivation through work recognition, appreciation, incentives etc.	0	1	2	3	4	5
e Top managements feedback time	0	1	2	3	4	5

II Technological sophistication

a Automation of design process	0	1	2	3	4	5
b Automation of manufacturing process	0	1	2	3	4	5

0 means not applicable
 1 means not important
 5 means very important

c Automation of testing process	0	1	2	3	4	5
d Automation of material handling	0	1	2	3	4	5

III Planning

a Pre-planned job allocation for each department	0	1	2	3	4	5
b R&D and Marketing department regular meetings/joint problem solving	0	1	2	3	4	5
c Designing and Manufacturing department regular meetings/joint problem solving	0	1	2	3	4	5
d Designing, Manufacturing & Marketing department regular meetings/joint problem solving	0	1	2	3	4	5
e Having formal check points or decision points after each stage	0	1	2	3	4	5

IV Organization dynamics (i.e., organization practices linked to the new product development)

a Formation of cross-functional teams comprising of members from all departments which are involved through out the innovation process	0	1	2	3	4	5

0 means not applicable
 1 means not important
 5 means very important

b Personnel orientation i.e.,
 giving first hand experience
 to person from one department
 in another department (e.g. R&D
 to production)

0 1 2 3 4 5

c Dedicating full time technical
 personnel for new product
 development

0 1 2 3 4 5

d Regular interaction with
 customers during the
 development process

0 1 2 3 4 5

e Parallel processing i.e.,
 process development and
 market development proceed
 simultaneously with the
 product development

0 1 2 3 4 5

V Supplier Relationship

a Involvement of suppliers at
 early stages of the innovation
 process such as during the
 designing of the components

0 1 2 3 4 5

b Visit of both parties i.e.,
 manufacturer and supplier to
 each others factories regularly

0 1 2 3 4 5

0 means not applicable
 1 means not important
 5 means very important

VI Decision on components to be manufactured internally

a Trade off between internal and external production
(i.e., produce only critical components internally and buy other components from outside vendor)	0 1 2 3 4 5

VII Quality of human resources

a Availability of diverse technically qualified personnel in the firm	0 1 2 3 4 5
b Past experience of employees in new product development activities	0 1 2 3 4 5
c Problem solving capability of the development team, particularly during crisis	0 1 2 3 4 5
d Flexibility of employee technical skills such as capability of performing different production related jobs etc.	0 1 2 3 4 5

VIII Budget and Funds

a Decentralized budget	0 1 2 3 4 5
b Availability of sufficient funds	0 1 2 3 4 5

0 means not applicable1 means not important5 means very important**IX Government policies**

a Less bureaucracy in
terms of seeking testing
approvals etc.

0 1 2 3 4 5

b Assistance from technical bodies
set up by govt., in case of
technical problems beyond firms
control etc.

0 1 2 3 4 5

c Extending financial support i.e.,
giving loans at low interest
rates for buying critical capital
equipments etc.

0 1 2 3 4 5

**X Marketing communication
& launch effort**

a Training of sales force

0 1 2 3 4 5

b Frequency of advertisements

0 1 2 3 4 5

c Extent of distribution network

0 1 2 3 4 5

XI Is there any other factor
you would like to mention.
If so, please use this space
for that purpose

a

1 2 3 4 5

b

1 2 3 4 5

c

1 2 3 4 5

Your contribution to this effort is very greatly appreciated. If you would like a summary of results, please indicate.

a. YES

b. NO

APPENDIX IV: TABLES 1-4

TABLE 1

	S.P	S.F	A.M.A
Possible Answers	M.F or T.R	Yes (Check mark) No (Blank)	Yes (Check mark) No (Blank)

Notation:**S.P = Starting Point****M.F = Market Finding****T.R = Technology Research****S.F = Strategic Focus****A.M.A = Advance Marketing Activities**

TABLE 2

	Starting Point	Strategic Focus	Advance Marketing Activities
Firm 1	T.R		
Firm 2	M.F	✓	✓
Firm 3	M.F		
Firm 4	M.F		✓
Firm 5	T.R		✓
Firm 6	T.R		✓
Firm 7	M.F	✓	✓
Firm 8	T.R	✓	
Firm 9	T.R	✓	✓
Firm 10	M.F		✓
Firm 11	M.F		✓
Firm 12	M.F		
Firm 13	M.F/T.R	✓	✓
Firm 14	T.R	✓	✓
Firm 15	M.F		✓
Firm 16	M.F		
Firm 17	M.F	✓	✓
Firm 18	T.R		✓
Firm 19	M.F	✓	✓
Firm 20	M.F		✓
Firm 21	M.F	✓	✓
Firm 22	M.F		✓

M.F = MARKET FINDING T.R = TECHNOLOGY RESEARCH

Notation: Yes (Check mark) No (Blank)

Note: Firms 1-4 are software firms. Firms 5-22 are hardware firms

TABLE 3

**POSSIBILITY OF DIFFERENT FEEDBACK MECHANISMS
BETWEEN ALL STAGES /DEPARTMENTS INVOLVED IN
THE INNOVATION PROCESS**

CUSTOMER	L2	L4	L8	L13		*
Q.A		L3	L7	L12	L16	
MARKETING	L1			L11		
PRODUCTION						
PROTOTYPE DEVELOPMENT & TESTING				L10	L15	
DESIGNING			L6	L9	L14	
R&D		**	L5			
	R&D	DESIGNING	PROTOTYPE DEVELOPMENT & TESTING	PRE- PRODN.	PRODUCTION	MARKETING

Note: Refer table in X-Y direction

Linkages L1 to L16 are explained on the following page

- * There is always a link between the Marketing department and the Customer
- ** There is always a link between the Designing stage and the R&D stage

POSSIBLE LINKAGES/FEEDBACKS BETWEEN DIFFERENT STAGES OF THE INNOVATION PROCESS

- L1 = Link between R&D and Marketing**
- L2 = Link between R&D and Customer**
- L3 = Link between Designing and Q.A**
- L4 = Link between Designing & Customer**
- L5 = Link between Prototype Development & Testing and R&D**
- L6 = Link between Prototype Development & Testing and Designing**
- L7 = Link between Prototype Development & Testing and Q.A**
- L8 = Link between Prototype Development & Testing and Customer**
- L9 = Link between Pre-production and Designing**
- L10 = Link between Pre-production and Prototype Development & Testing**
- L11 = Link between Pre-production and Marketing**
- L12 = Link Pre-production and Q.A**
- L13 = Link between Pre-production and Customer**
- L14 = Link between Production and Designing**
- L15 = Link between Production and Prototype Development & Testing**
- L16 = Link between Production and Q.A.**

TABLE 4

	L 1	L 2	L 3	L 4	L 5	L 6	L 7	L 8	L 9	L 10	L 11	L 12	L 13	L 14	L 15	L 16
F1		✓	✓			✓	✓	✓		✓	✓	✓	✓			
F2	✓		✓	✓		✓	✓	✓								✓
F3	✓	✓	✓			✓	✓									
F4		✓				✓		✓			✓		✓		✓	
F5			✓	✓		✓		✓			✓		✓			
F6	✓	✓	✓		✓	✓	✓	✓						✓		✓
F7	✓		✓				✓	✓			✓	✓	✓			
F8		✓	✓	✓		✓	✓	✓			✓	✓	✓	✓		✓
F9		✓	✓			✓	✓	✓	✓			✓				
F10	✓					✓	✓	✓								✓
F11	✓		✓					✓	✓						✓	
F12	✓					✓					✓					
F13	✓	✓	✓			✓	✓					✓	✓	✓		✓
F14		✓	✓			✓	✓	✓						✓		✓
F15	✓			✓		✓		✓			✓	✓	✓			
F16	✓					✓	✓	✓			✓	✓		✓		
F17	✓					✓			✓			✓	✓	✓		✓
F18	✓					✓		✓						✓		
F19	✓					✓	✓	✓				✓		✓		
F20	✓	✓		✓		✓							✓			✓
F21	✓		✓	✓		✓	✓	✓						✓		
F22	✓	✓				✓		✓						✓		✓

L stands for linkages/feedback mechanisms possible between various stages of the innovation process. L1 to L 16 linkages have been explained on the preceeding page. Further, firms 1-4 are Software firms whereas firms 5-22 are hardware firms. Notation: Yes (Check mark) No (Blank) F stands for firms

END

15-1 2-93

FIN