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**A FRAMEWORK TO DECIDE WHEN TO TERMINATE ONGOING R&D
PROJECTS IN CANADIAN HIGH-TECHNOLOGY INDUSTRIES**

by

**Aditha N.S. Persaud, B. Soc. Sc.(Economics)
M.A. (Banking and Finance)**

A thesis submitted to
Faculty of Graduate Studies and Research
in partial fulfilment of
the requirements of the degree of
Master of Management Studies
School of Business
Carleton University
Ottawa, Ontario
December 4, 1992

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**A FRAMEWORK TO DECIDE WHEN TO TERMINATE ONGOING R&D
PROJECTS IN CANADIAN HIGH-TECHNOLOGY INDUSTRIES**

submitted by Aditha Narayan Sharma Persaud, B. Soc.Sc.; M.A.
in partial fulfilment of the requirements for the degree of Master of Management Studies

Dr. Vinod Kumar, Thesis Supervisor

Dr. Uma Kumar, Thesis Supervisor

Dr. Roland Thomas, Chair, School of Business

Carleton University

December 4, 1992

Abstract

This study used the technique of multiple logistic regression to determine those factors which discriminate between success and failure of a R&D project at its different stages. Based on the results of the logistic regression models, a new methodology for monitoring R&D projects throughout their lifetimes has been developed. The monitoring framework advanced in this thesis represents a major departure from the current monitoring practices of firms. The major advantage of the proposed approach is that it provides a single indicator of success of a project based on the combined effect of all relevant variables. Thus, it avoids the problem of setting thresholds for individual variables or indicators of success. Finally, the technique of logistic regression requires fewer restrictive assumptions than multiple discriminant analysis which has been used in earlier studies.

Table of Contents

	Page
Acceptance Sheet	ii
Abstract	iii
Acknowledgements	iv
Table of Contents	v
List of Tables	vi
List of Figures	vii
CHAPTER 1: INTRODUCTION	1
CHAPTER 2: LITERATURE REVIEW	
2.0 Introduction	4
2.1 Definition of Innovation	4
2.2 Models of the Innovation Process	6
2.3 Success and Failure of Innovations	11
2.4 Termination of Innovations	22
2.5 Summary	27
CHAPTER 3: THE STUDY	
3.0 Introduction	29
3.1 Activity-Decision Stage Model	29
3.1.1 Initial Screening	30
3.1.2 Commercial Evaluation	32
3.1.3 Development	32
3.1.4 Manufacturing and Marketing Launch	33

	Page
3.1.5 Initial Commercialization	33
3.2 Success and Failure Variables	33
3.3 Research Objective	34
3.4 Methodology	34
3.5 Quantitative Model	38
3.6 Data Analysis	40
3.6.1 Analysis A1	42
3.6.2 Analysis A2	42
3.6.3 Analyses A3 and A4	43
 CHAPTER 4: DISCUSSION OF ANALYSES A1 AND A2 RESULTS	
4.0 Introduction	44
4.1 Model Assessment Framework	44
4.2 Analysis of A1 results	45
4.3 Analysis of A2 results	48
4.3.1 Decision Stage 1	48
4.3.2 Decision Stage 2	48
4.3.3 Decision Stage 3	51
4.3.4 Decision Stage 4	51
4.4 Analysis A1 versus Analysis A2	54
4.5 Explanation of Variables	54
4.5.1 Corporate Fit	56
4.5.2 Science and Technology	57
4.5.3 Reaction	58
4.5.4 Potential Uses of Project	58

	Page
4.5.5 Firm's Technical Capability	59
4.5.6 Efficiency of the Development Process	59
4.5.7 Commercial and Technical Coupling	60
4.5.8 Marketing Effort	61
4.6 Summary of Results	62
 CHAPTER 5: RESULTS AND IMPLICATIONS OF ANALYSES A3 AND A4	
5.0 Results of Analyses A3 and A4	62
5.1 Implications of A3 and A4 Results	62
5.2 Re-examination of Analyses A1 and A2 Results	63
5.3 Summary	66
 CHAPTER 6: THE MONITORING FRAMEWORK	
6.0 Preamble to the Framework	67
6.1 The Framework	69
6.2 Operationalizing the Framework	71
6.3 Summary	73
BENEFITS OF STUDY	74
LIMITATIONS OF STUDY	75
CONCLUSION	76
APPENDIX 1: Definition of Variables	78
APPENDIX 2: Interview Schedule	81
APPENDIX 3: Adjusting the Constant Term	87
APPENDIX 4: Dimensions of Firm's Review Process	89
REFERENCES	91

List of Tables

	Page
Table 1: Summary of Articles on Success and Failure of Innovations	12
Table 2: Summary of Findings from Previous Success and Failure Studies	13
Table 3: General Profile Of Participating Firm	38
Table 4: Results of Analyses A1	47
Table 5: Results of Stage - One	49
Table 6: Results of Stage - Two	50
Table 7: Results of Stage - Three	52
Table 8: Results of Stage - Four	53
Table 9: Results of Analyses A3 and A4	65

List of Figures

	Page
Figure 1: Definitions of Success and Failure	20
Figure 2: Activity-Decision Stage Model of the Innovation Process	31
Figure 3: Quantitative Model	39

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CHAPTER 1

INTRODUCTION

Research on R&D management has focused mainly on the innovation process, project selection decisions, and the success and failure of innovation projects¹. However, very little research has been done on the termination decision of a R&D project leading to innovation, in spite of the fact that this is one of the most difficult decisions facing management.

The decision to terminate an ongoing research project before it achieves its original goals is not only difficult but also important. It is difficult because it means accepting failure, which very few managers are willing to acknowledge, may involve political considerations and may affect the morale of the project team. It is important because of the rapid increase in the cost of R&D and the need to optimize available resources. A correct decision to terminate a project at the right time can save time, money and other resources, which can be redirected towards more promising and potentially successful projects. On the other hand, a wrong decision to terminate a project may give a big competitive advantage to competitors. In addition, the high failure rate makes it necessary for the firm to have a clear understanding of the causes of failure and to develop a systematic procedure for terminating the innovation at the right time. Myers and Sweezy (1978) noted in their study that it takes about 58 ideas to yield a new product and only about 10 to 12 percent of the ideas submitted for initial screening enter the development pipeline toward commercialization. Further, these authors noted that approximately 19% of innovations are stopped in the final and most expensive phase of the innovation process, production installation.

1. Innovation projects may refer to either new products and/or processes. Success refers to both technical and commercial success.

In light of the importance of the termination decision, it is both necessary and urgent to develop a systematic approach for monitoring R&D projects. This approach will assist in the early identification of problems facing a project so that remedial action could be taken to ensure that resources are not wasted.

The objective of this study is to develop a systematic and structured framework which could be used to decide when to terminate an on-going R&D innovation project. The framework to be developed in this study is based on the notion that the factors which determine the outcome of a project vary according to the stage of the innovation process. To develop this framework will require at least three intermediate steps, namely, modelling of the innovation process, identifying the variables which determine success or failure, and ascertaining which of these variables are crucial to the various stages during the life of the project. The first step, modelling the innovation process, will be based on a synthesis of the various models of the innovation process advanced in the literature. The list of success/failure variables will be drawn from the literature as well as from a survey of R&D managers. Once the variables which are crucial to each stage of the innovation process are identified, then we can develop an appropriate monitoring mechanism which could be used for the continue/terminate decision.

This thesis is divided into six chapters. The first chapter introduces the study. The second chapter reviews the relevant project management literature. The review is designed to ascertain the direction of research within the area of project termination and to place this study in perspective. The third chapter provides a brief description of the study, i.e., the research objective, methodology and data analysis techniques used. The results and implications of the various analyses conducted are discussed in the fourth and fifth chapters. Chapter six describes the framework developed in this thesis. Finally, the

benefits, limitations and conclusions of the study are stated.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This section reviews three aspects of the project management literature, namely, the innovation process, factors affecting success or failure of projects and project termination decisions. The literature on the innovation process is examined in order to develop a clear understanding of the innovation process from which a model of the process is developed. The resulting model along with the factors that determine the success or failure of innovations is linked to determine which factors are most crucial to the various stages of the innovation process. Finally, the literature on termination decisions is reviewed in order to place our study in perspective.

2.1 Definition of Innovation

In the literature there is no single definition of innovation or the innovation process, although there is some agreement on certain aspects of the innovation process. For example, Mueser (1985) claimed that there is strong agreement on the definition of technical innovation in about three-quarters of the 350 references he reviewed. According to him, the consensus definition of technical innovation is "a new idea, a discontinuous technical event that, after a period of time, is developed to the point where it is practical and successfully used" (p. 159). This definition of technical innovation implies that the innovation process has distinct starting and ending points. Mueser (ibid) further argued that an innovation is not an innovation if it is nontechnical, incremental and unsuccessful.

Schumpeter (1939) believed that innovation is distinctly different from invention which may occur in isolation of innovation and which could or could not be coupled with

innovation. According to this view, innovation is characterized by the construction of new plants and equipment, introduction of new firms, and the rise to leadership of new men. From this perspective, innovation is a discontinuous event (cited in Robertson 1967 p. 14). Barnett (ibid, p.15) defines innovation as "any thought, behaviour, or thing that is new because it is qualitatively different from existing forms". According to Saren, "innovation is the process by which an invention is first transformed into a new commercial product, process or service. It is different from both invention - discovery of a new technique, and diffusion - the adoption of the innovation" (p. 12).

It is observed that most studies use the term "Research and Development" to refer to the innovation process although conceptually R&D is distinct from the innovation process. R&D refers to the activities undertaken to acquire and increase the stock of knowledge and to use this knowledge for developing new or significantly improved products, processes or service. A 1973 Statistics Canada survey of technological innovation describes a 'typical' innovation as consisting of seven different activities: R&D, new product marketing, patent work, financial and organizational changes, final product or design engineering, tooling and industrial engineering, and manufacturing startup. In (Kumar and Kumar, 1991, pp. 3-4), innovations are considered to involve the following activities: applied research, preparing specifications, developing a prototype or pilot plant, developing tooling, plant and facilities, manufacturing startup, and marketing startup.

It is obvious that the preceding definitions of innovation imply that all innovations are discontinuous events. However, several scholars (e.g., Rogers, 1983) have argued that not all innovations are discontinuous and that the majority of innovations are the result of small changes accumulated over time. From this perspective innovations have been classified into three categories namely, continuous, dynamically continuous and

discontinuous innovations. Continuous innovations have the least disrupting influence on established patterns. Alteration of a product is involved, rather than the establishment of a new product. Dynamically continuous innovations have more disrupting effects than continuous innovations although they still do not generally alter established patterns. It may, however, involve the creation of a new product or the alteration of an existing product. Discontinuous innovations involve the establishment of a new product and new behaviour patterns.

In summary, it is clear that innovations can be seen as a process with distinct starting and ending points, could be incremental or discontinuous, and must end in successful commercialization. For this study, innovation will be defined as the development and first commercialization of a new product, process or service. The definition of the innovation process by Kumar and Kumar (1991, pp. 3-4) is adopted in this study

2.2 Models of the Innovation Process

Several models of the innovation process have been advanced by various researchers. The majority of the models portray the innovation process as a linear progression through a number of stages beginning with some idea and ending with a new product in the market. However, this linear representation of the innovation process was strongly challenged by Stephen Kline (1985) who claimed that it is "so oversimple and inadequate that it must seriously distort thinking about the innovation process" (p. 36). He developed the so-called "chained linked" model which depicts the innovation process as strictly non-linear with a number of feedback loops both within and between the various stages of his model. Although his model was developed based on his extensive experience as a consultant in a number of industries it has never been rigorously tested empirically. Further, the innovation process can be viewed from two perspectives: the producers' perspective and

the users' perspective (NSF 1983 p. 21). The producers' perspective focus more on the front end activities of the innovation such as basic research, applied research, design, prototype and development of the technology. Generally, most of the models which attempt to describe the innovation process focus more on the producers' perspective. The users' perspectives focus more on the activities related to the adoption of an innovation by a firm. For example, office automation may be regarded as an innovation from the perspective of the organization that is adopting the change.

A cursory examination of these various modelling frameworks reveals the complexity and controversy that is associated with the innovation process. It is therefore not surprising that to date there exists no generalized model of the innovation process. In reviewing these models, we will utilize the classification schema developed by Saren (1984) who classified the various models of the innovation process into five categories, namely, departmental-stage models, activity-stage models, decision-stage models, conversion process models and response models.

Departmental-stage models view the innovation process as a series of stages associated with the various departments within the firm (e.g., Robertson 1974). That is, the innovation process begins with an idea and this idea moves through the various departments (R&D, Design, Engineering, Production, Marketing) sequentially until it finally emerges as a new product in the market. Although these types of model provides a simple representation of the innovation process, they do not show the changes carried out on the innovation within each department (except for its title). Also, these models assume that the contribution of each department to the innovation process ends once the innovation has moved out of one department and enters into another department. This implies that there is no feedback between departments or reversal of the process. This is clearly not an

accurate representation of the innovation process.

Activity-stage models break down the innovation process into a series of activities in a sequence (e.g., Kotler 1976; Baker and McTavish 1976; King 1973; and Cooper 1983).

Rothwell and Robertson (1973) describes the innovation process as

"a logically sequential, though not necessarily continuous process which can be subdivided into a series of functionally separate, but interesting and interdependent stages, and the overall pattern of the innovation process can be thought of as a complex net of communication paths linking the various stages of the process" (cited in Saren 1984 p.13).

It is noted that the number of stages and the links between the various stages in the innovation process may differ depending on whether the researcher wants to define the innovation process per se (e.g., Kline, 1985) or simply needs a descriptive model to analyze the factors associated with or affecting the process. For example, Utterback (1974) identifies three clear stages of activities: 1) idea generation, 2) problem solving or idea development; invention, and 3) implementation or bringing the solution or invention to the marketplace, involving engineering, tooling, manufacturing, test marketing and promotion. Similarly, Baker and McTavish (1976) and Kotler (1976) identified six stages - idea generation, screening, commercial evaluation, technical development, testing and commercialization. Pinto and Slevin (1989) used a four-stage model of the innovation process to analyze the critical success factors in R&D projects. Pinto and Mantel (1990) used a two-stage innovation process model to analyze the causes of project failure.

It is also important to note that the time and effort required for each stage of the innovation process varies considerably i.e., some stages are shorter and require less effort than others. The activity-stage models, unlike department-stage models, give more information about the activities that are carried out at each stage of the process, more is also known of the

form of the potential new product as it passes between stages and the distinction in stages are clearer when based on activities in this way. However, this approach gives no indication of the alternative paths available at particular points in the process and also ignores feedback between stages.

Grandstand and Fernlund (1978) and Twiss (1980) attempted to link the activity breakdown with the department approach to show how various activities are associated with different departments. This type of model is particularly useful for analyzing problems of coordination caused by the number of functions and departments involved in the innovation process. The Twiss model shows what form the innovation takes as it passes from stage to stage and illustrates the 'gatekeeper' role of departments in the innovation process. The main shortcoming of this modelling framework is that these models do not synchronize exactly.

Decision-stage models view the innovation process as series of decisions (e.g., Rubenstein and Ettlie 1979 and Cooper and Moore 1979). Robertson and Fox (1977) see the process of innovation as a series of decisions made by managers according to the quality of information available to these managers. Decision-stage models provide a more practical basis for examining the innovation process because they recognize the number of options available and that decisions are based on less than perfect information. Another strength of this type of model is that they can be used to identify common building blocks and decision and action points in the innovation process. Finally, decision-stage models can make use of the analytical techniques of decision theory, probability analysis and computer simulation.

Conversion process models view the innovation process as a conversion process whereby

input such as, raw materials, scientific knowledge and manpower, are transformed into outputs - new products (Twiss 1980 and Schon 1967). The input may take the form of activities, information and departments, but in no specific order. Thus, conversion-process models identify both activities and departments.

Finally, Response models portray the innovation process as a four-stage process involving Perception - Search - Evaluation - Response (Becker and Whistler, 1967). Here, the individual must first recognize the change, then seek information about its effects, analyze the implications of these for himself/herself and finally react to the change. From this perspective, innovation is seen as the firm's 'response' to some internal or external stimulus. This type of model reflects a more user-oriented view of the innovation process mentioned earlier. Perhaps, the major shortcoming of response models is their overemphasis on the earlier parts of the innovation process and the lack of attention to the development and testing stage.

A careful examination of the various modelling frameworks described above suggests that a number of advantages can be achieved by combining the activity-stage and the decision-stage approaches. This is because an activity-decision stage model gives more information about the innovation as it passes through each stage of the innovation process and the various stages can serve as checkpoints in the monitoring process. It does recognize that decisions are based on incomplete information, can incorporate feedback and reversal in the process and can also accommodate the use of decision tools and other quantitative techniques. In light of these strong features, the model used in this study is based on a combination of the activity and decision-stage frameworks.

2.3 Success and Failure of Innovations

We will now review the literature on the success and failure of innovations. The literature shows that the success or failure of a R&D project is determined by a combination of factors rather than any single factor. However, there is no consensus on the precise set of factors that determine the outcome of a project. Table 1 summarizes the main features of a number of previous success/failure studies and Table 2 shows the main success/failure factors identified in previous research. Cooper (1979) identified 77 variables and Rothwell (1974) 60 variables which could be used to classify innovation projects as either success or failure. However, many of these variables are highly intercorrelated and can be reduced to a meaningful and manageable set. Some of the more common variables which were found to be important in determining innovation success/failure include the following: understanding user needs (11 studies), efficient performance of development process (7), market pull (7), good fit with company potentials and resources (6), better coordination of R&D, Marketing and Production (9), and top management support and the existence of a product champion (9).

Another study, Baker et al., (1986) claimed that some factors that determine the outcome of an innovation are specific to the line of business of the project while others are general enough to be applied to any project regardless of line of business. In this study, the authors analyzed 211 R&D projects from a database developed by the Industrial Research Institute and the National Science Foundation. The study was carried out in 21 firms in four lines of business: low carbon, flat rolled steel, agricultural and industrial chemicals, and packaged processed foods. They found six (6) statistically significant success/failure effects which they referred to as "main effects" and several statistically significant "second-order effects" which relate directly to line of business and type of expected outcome. The main effects show that projects are likely to be more successful when:

Table 1

Summary of Articles on Success and Failure of Innovations

Author and Date of Publication	Type of Study	Industry Studied	Unit of Analysis	Sample Size	Statistical Technique
Baker et al. (1986)	empirical	flat steel	firm	211	not stated
Balachandra & Raelin (1985)	empirical	high-tech	project	51	discriminant
Buell, C.D. (1967)	conceptual	not stated	project	none	discussion
Cooper, R.G. (1979)	empirical	not stated	firms	195	factor & discriminant
Cooper, R.G. (1986)	empirical	electronics	firms	97	Factor & discriminant
Cooper & Kliens Schmidt (1990)	empirical	chemicals ²	project	250	simulation
Drucker, P. (1985)	conceptual	not stated	not stated	none	discussion
Holzmann, R. (1972)	conceptual	not stated	not stated	none	discussion
Maidique & Zirger (1984)	empirical	electronics	firm	158	cluster
Myers & Swezey (1978)	empirical	not stated	not stated	200	discussion
Pinto & Slevin (1989)	empirical	computer	project	159	regression
Tadsina, S. (1986)	empirical	flat steel	project	220	discriminant
Bedell, J. (1983)	conceptual	not stated	not stated	none	discussion
Rothwell et al. (1979)	empirical	chemical & scientific instrument	project	86	principal components & factor analyses

1. Other industries included agricultural chemicals, packaged processed foods, and industrial chemicals

2. Other industries include electrical, electronics, heavy and light equipment, material and components, and miscellaneous

Table 2

Summary of findings from previous success and failure studies

Success & Failure Variables	Research Study
External	
Technology push	5, 6, 7
Market competitiveness	6, 8, 12, 13, 17
Government regulations	1, 4, 5, 6, 9, 14
Market pull	1, 2, 3, 4, 5, 6, 8
Industry maturity	4, 6, 8, 9
Science & Technology	9, 10, 11, 12
Business Cycle	5, 6, 9
Organizational (internal)	
Good fit with company potentials, resources	3, 8, 11, 12, 13, 14, 17
Better internal and external communication	1, 2, 3, 4, 5, 6, 11, 14
Better coordination of R&D, Marketing, Production	1, 2, 3, 6, 8, 9, 12, 13, 14
Product champion or top management support	1, 2, 4, 6, 10, 11, 12, 13, 14
Better planning and systematic approach to innovation	1, 3, 4, 5, 6
Efficient performance of development process	1, 2, 3, 6, 11, 13, 14, 17
Understanding project mission	10, 11, 12, 14
Availability of information	14
Marketing	
Understanding user needs	1, 2, 3, 4, 6, 8, 9, 11, 12, 13, 14
Extent of customer-producer interfacing	1, 2, 3, 4, 6, 11
Level of sales forecasting carried out	1, 2, 6, 12, 14
Strong promotional & user education effort	1, 8, 13
Strong selling (and marketing) effort	1, 2, 3, 6, 8, 13
Close to current market (familiarity with market)	1, 3, 4, 8, 10
Fewer after sales problems	1, 2, 3, 4, 6, 11
No initial marketing difficulties	4, 9
Product/Process	
Product and/or price advantages	4, 7, 8, 13, 17
New product introductions	8, 12, 13, 17
Stage of product in product life cycle	8, 12
Product contribution to the firm	13, 14
Expected outcomes	10, 11, 12, 14
Technical characteristics of product/process	8, 10, 13, 14, 17
1. Rothwell 1972; Rothwell et al 1974	9. Myers and Sweezy 1978
2. Rothwell 1974 (Hungarian SAPPHO)	10. Baker et al 1986
3. Kulvik 1977	11. Pinto & Slevin 1989
4. Utterback et al 1976	12. Balachandra & Raelin 1985
5. Gerstenfeld 1976	13. Maidique & Zirger 1984
6. Rothwell 1976	14. Rubenstein et al 1976
7. Davidson 1976	15. Teubal & Spiller 1977
8. Cooper 1979	16. Pinto & Prescott 1988
	17. Cooper and Klienschmidt 1988

- (a) the firm is more experienced in producing and selling the product, or in using the process;
- (b) the greater the level of general management involvement;
- (c) the project business and technical goals are well defined and widely recognized particularly in the later stages in the life of the project; and
- (d) the greater the impact and contributions of the project to the firm.

The second-order effects identified are: project-company fit; experience and familiarity of firm's R&D unit with the Science and Technology (S&T) underlying the project; project complexity; expected contribution at initiation; cost to do R&D in the S&T area; expected project outcome (projects expected to result in new or modified products/processes are more likely to succeed); and market-pull. Finally, the authors argue that industrial products are more likely to succeed than consumer products because of underlying market/customer differences between these two market segments. For industrial projects, clients are usually other industrial firms which are fewer in number than consumer markets. They are relatively easier to identify, interact more closely with supplier firms so that their needs are better understood and they can exert pressure which may facilitate the commercialization of the project outcomes. Therefore, uncertainty concerning the objective and sales opportunity are greatly reduced.

Rothwell et al. (1974) conducted a study based on a pairwise comparison of successful and failed innovations to determine if there are any underlying characteristics that distinguish these innovations. The comparison was based on 122 'measures' which covered areas relating to the innovations itself, the firm, its marketing, R&D, production etc. In phase I, 29 pairs of innovations were examined, 17 in chemical processes and 12 in scientific instruments. In phase II the sample increased to 43 new pairs, 22 in chemicals and 21 in

scientific instruments. The two main analytical techniques utilized in this study were principal component analysis and classical factor analysis. The authors found that successful innovators understood user needs better, undertook marketing more proficiently, perform their development work more efficiently than failures but not necessarily more quickly, made greater use of outside technology and scientific advice, and the project leader was usually more senior with greater authority. Also, project outcomes were affected by technical and market uncertainties as well as certain environmental and structural differences between the two industries studied.

Cooper (1979) conducted an empirical study of 102 successful and 93 failed innovations from 103 firms from Ontario and Quebec. He also used a pairwise comparison technique along with factor and discriminant analyses to isolate the major determinants of success/failure. The key success factors were product uniqueness and superiority, market knowledge and marketing proficiency, and technical and production synergy and proficiency. Three barriers to success are having a high-priced product, being in a dynamic market and being in a competitive market where customers are satisfied. Three facilitators of success are marketing and management synergy, strength of marketing and launch effort and market need, growth and size. Two weakly related variables are newness to the firm or first to the market and market derived idea or customer suggested innovation.

Myers and Sweezy (1978) examined 200 innovations that passed initial screening but failed after entering the commercialization pipeline for the Denver Research Institute. Their results indicate that uncontrollable market factors, limited sales potential, inability to find buyers, poor management and government Laws and Regulations are the main causes for innovation failures.

Pinto and Slevin (1989) analyzed 159 R&D projects in the following areas: new drug R&D, chemical and petrochemical process research, aerodynamic engineering research and computer hardware and software development. The authors found ten factors critical for R&D project success. However, they concluded that the relative importance of these factors change depending upon the stage at which the project resides, i.e., the factors are not always of equal and stable importance across the entire life of the project. They used a four-stage model of the innovation process along with stepwise regression analysis to identify the factors relevant to each stage. The four stages of the innovation process together with the factors relevant to each stage were as follows:

Conceptual: project mission, client consultation, availability of suitable personnel, urgency, i.e., the perception of the importance of the project or the need to implement the project as soon as possible.

Planning: project mission, environmental effects and client acceptance

Execution: project mission, technical tasks, and top management support.

Termination: project mission, schedule, client acceptance, technical tasks and personnel.

Modesto Maidique and Billie Jo Zirger (1984) conducted a three-phase study of firms in the U.S Electronics Industry to determine the causes of success or failure of innovations. This study conducted a pairwise comparison of two innovations - the one a success, the other a failure - within a given firm. Each phase was conducted serially to provide progressive hypothesis refinement and validation. The first part of the study utilized an open-ended survey which was completed by 79 respondents, mainly, presidents, vice-presidents or senior functional managers of U.S electronics firms. In the second phase, a detailed interview schedule was used and 59 of the 79 participants from phase one completed this survey. The third phase consisted of 20 indepth case studies of companies that took part in

the two earlier phases. Each respondent was asked to select a pair of innovations - one success and one failure - within his firm and to identify the reasons for the success or failure of the innovation pair. The criterion for differentiating between success and failure was whether the innovation did or did not achieve financial breakeven. The factors given for the success or failure were grouped into three broad categories: environmental variables; corporate skills and resources; and products and product strategy. According to this study, new product success is more likely when the developing organization, through indepth understanding of the customers and the marketplace, introduces a product with a high performance-to-cost ratio; is proficient in marketing and commits a significant amount of its resources to selling and promoting the product; the product provides a high contribution to the firm; the R&D process is well planned and executed; the R&D, production and marketing functions are well interfaced and coordinated; the product is introduced into the market early; the markets and technologies of the new product benefit significantly from the existing strengths of the developing business unit; there is a high level of management support for the product from the development stage through its launch to the market place. The technological capability of innovations were not considered because the projects studied were considered by management as technologically feasible.

Teubal and Spiller (1977) examined 18 failed innovations in the Israeli biomedical electronics sector under the following four general headings: Stage of program suspension; Events leading to suspension ; Evaluation of firm behaviour, and Interpretation of firm behaviour. They found that most failed programs were influenced by inadequate program selection which should be regarded more as a fundamental cause of failure. Inadequate program selection is the result of insufficient exploratory search largely influenced by a management view that underestimates the importance of the marketing aspects in the innovation process. Inadequate program execution is often merely a reflection of

inadequate selection.

Balachandra and Raelin after reviewing the literature and analyzing 51 high-tech R&D projects claimed that the success of an innovation depends on the level of top management support; the existence of a product champion; the effectiveness of the project manager to resolve quickly unanticipated problems; the rate of new product introduction; the coordination of the marketing and technical aspects of the project; the commitment of the project workers; the probability of technical success; technological route, i.e., the firm should select the technology for the project and should stay on track with this technology; end uses of the innovation; the life cycle of the product - the risk of failure is greater if the new product is from a group which is in the infancy stage of the life cycle rather than in its growth stage; the level of internal competition and observing time and cost schedules.

In spite these findings, there is some disagreement among researchers concerning the significance of some of the variables used to explain R&D success/failure. For example, both Cooper (1979) and Maidique and Zirger (1984) found the *characteristics of the product* to be highly significant whereas Rothwell (1974) found this variable to be insignificant. In addition, the *characteristics of the marketplace* was not a major variable in either Cooper (1979) and Rothwell (1974) but was an important variable in Maidique and Zirger (1984). Similarly, the finding by Rubenstein et al.(1976) that the existence of a well run organization are not sufficient conditions for R&D success contrasts with most previous studies. Even the popular finding that most successful innovations are derived from the market - "market pull" - was sharply criticized by Mowery and Rosenberg (1979).

Several factors may account for the observed differences in the results of these studies. One of the main reasons for the disagreement may be methodological. The method of data

collection and analysis utilized in the studies vary widely and in many cases the researchers may not have been measuring the same things in the same ways, although in some cases the nominal definitions of the variables may have appeared to be similar. It was found that in several studies the operational definitions are often vague and inconsistent (see Figure 1). Maidique and Zirger (1984) defined success in terms of financial breakeven whereas Cooper (1979) defined success in terms of profitability. These differences are important since it was found that the decision to classify an innovation as either a success or failure is closely related to the definition of failure (Pinto and Mantel, 1990).

Rubenstein et al. (1976) distinguished between technical, commercial and overall success without defining these terms. The authors contended that this distinction is important since it helps explain the difference in perception between R&D personnel and other functional staff (e.g. Marketing), including top management. This distinction has implications for the data used in the studies. The data used in the studies invariably come from different respondents, and it is possible that perception about R&D barriers and facilitators vary widely among functional units, professional specialties, management levels, and different levels of experience in the organization. This may lead to some amount of response bias which may distort the results of the studies. Maidique and Zirger(1984) found that the experiential background of marketing executives and the technical people to be significantly different. For example, marketing executives placed greater emphasis on planning, value to the customer, and timing of market entry, whereas technical people placed greater emphasis on staying close to existing company strengths and on coupling to other functions within the company. In addition, sample sizes are typically small; their method of selection is often suspect; data analysis technique are naive. For example, the landmark study done by Myers and Marquis (1969) which is widely quoted in the literature considered only successful innovations whereas Teubal and Spiller considered only failed innovations.

Figure 1
Definition of Success and Failure

Baker et al. (1986): Defined success in terms of technical and commercial success - no definition was given for "technical" and "commercial".

Cooper (1979): Success is defined in terms of profitability i.e. the degree to which a product's profitability exceeded, or fell short of the minimum acceptable profitability for this type of project or investment regardless of the firm measured profitability.

Maidique & Zirger (1984): Success and failure was differentiated by whether the innovation did or did not achieve financial breakeven.

Pinto & Slevin (1988): Measured success with an average of 13 items, including level of adherence to budget and tentative schedules, project performance capabilities, user acceptance and usage of the product, and user benefits from the project.

Rothwell et al. (1974): A successful innovation is one which obtains a worthwhile market share and profit, and a failure is one which fail to achieve this.

Cooper and Klienschmidt (1991): The degree to which the products profits exceeded or fell short of the firms acceptable profitability criteria for new product investments.

Another consideration is that of the unit of analysis which has been different in most of the studies. For example, some studies focused on the firm, some on a division of a firm or conglomerate and some on the project level. Apart from the differences in the unit of analysis, there are differences with regard to the size and type of the unit. For instance, some studies focused on large firms only whereas others included both large and small firms. Regarding the type of unit chosen for analysis, some studies examined industrial innovations whilst others analyzed consumer innovations. This latter distinction is very important since it is acknowledged in the marketing literature that the market/customer characteristics of these two market segments vary significantly. These differences could play a significant role in determining the outcome of a project. Finally, there is a paucity of studies which attempt to build conceptual models to address the issue of innovation success and failure. Consequently, there appears little logic or consistency in the variables any particular researcher chooses to measure. In fact, a number of these studies are purely descriptive and is based on experience and/or interviews with individuals within the organization which was studied.

In conclusion, we note that although there is widespread agreement among researchers that project outcomes are determined by a number of factors, there is still much controversy concerning the precise set of factors. Further, the innovations, nominal definitions, sample size, methodology, data analysis techniques, respondents, and unit of analysis vary widely from study to study and these dimensions may have significantly influenced the results obtained from these studies. Finally, because there is a paucity of studies which attempt to build conceptual models to address the issue of innovation success and failure, there appears to be little consistency in the variables any particular researcher chooses to measure.

2.4 Termination of Innovations

As noted earlier, there is a paucity of research on the termination of R&D innovation projects. Balachandra and Raelin (1980), Tadsina (1986) and Shafer and Mantel (1986) offered a number of explanations for the lack of research in this area. One reason is the difficulty involved in setting down specific and reasonable guidelines that are applicable to all situations, i.e., to diverse projects with different scope, complexity and other organization-specific conditions. In this case, the decision to terminate may involve complex quantitative models which may be discouraging to decision-makers who may prefer to base their decisions upon subjective judgements, educated guesses or even personal interests. Also, in many cases the decision has to be made by several individuals within the organization who have different backgrounds, viewpoints and objectives. Another reason is that the termination of a project usually reflects the failure of someone, mostly the management of the organization, and very few persons are willing to acknowledge the existence of such situations. Finally, in most cases the decision to terminate an innovation is not arrived at suddenly but rather develops gradually. So whenever the decision is finally made it is just a matter of going through the motions. Thus, the precise causes leading to the termination decision is not clearly defined.

Despite the difficulty involved in developing models for the termination decision, researchers have dedicated some effort to this question, and indications are that more attention is currently being paid to this question. In our literature search we identified eight studies which specifically addressed the issue of when to terminate an ongoing innovation project. These studies were done by Buell (1967), Holzmann (1972) and Balachandra and Raelin (1980, 1984 and 1985), Bedell (1983), Shafer and Mantel (1986), and Tadsina (1986). Most of the research did not utilize any systematic empirical method for arriving at

the termination decision. Rather, they just develop a series of questions about the project and the organization and apply some basic decision rules which are checked against some minimum standard. Balachandra and Raelin (1980, 1984 and 1985) and Tadsina (1986) developed and applied an operational and systematic procedure to monitor innovations based on discriminant analysis. These eight studies are reviewed in the remainder of this section.

Buell's (1967) study represents one of the earliest attempts to address this very important question of when to terminate a research and development project. Based on his experience, he suggested a number of questions which should be considered before deciding to abandon a project. His questions covered some important issues such as, the firm's continued interest in the project, expected profitability of the project, congruence of the project with the overall company goals and strategy, management support and the existence and influence of a project champion. Other issues were the company's ability to finance and commercialize the project, the commitment of project workers, level of support and opposition from other departments and influential individuals within the organization. Buell proposed that the decision to terminate a project cannot be expressed "in a neat set of mathematical expressions" and therefore did not offer any quantitative decision models nor state any procedure for answering his set of 21 questions. Thus, these questions were not tested for their validity and usefulness.

Holzmann (1972) argued that R&D projects should be terminated when it is determined that they are technically infeasible or economically unsound. According to him, the decision to start a project does not mean that the project must continue indefinitely. However, he did not specify any systematic procedure for determining which projects are technically infeasible and/or economically unsound.

Balachandra and Raclin (1980) developed a discriminant model to represent the termination decision. The discriminant factors used in the study were developed through discussions with R&D managers and a review of the available literature. A set of 23 factors, 10 quantitative and 13 qualitative, were identified as having the "ability to evaluate the changes in the attractiveness of a project since it was started". The quantitative factors dealt with those aspects of the project which could be measured objectively. These factors were: the probability of commercial success, anticipated annual growth rate, capital requirement, risk distribution, return on investment, profitability, annual cost of project/R&D budget, probability of technical success, fraction of times time-schedules met and the fraction of times cost-schedules met. The qualitative factors which are not easily measurable objectively are: disposition of major consumer groups; probability of restriction from government regulation; ability to react successfully to competition; degree of innovation, linkage with other ongoing projects, support from top management, commitment from project leader, commitment from project workers; and the influence of the project leader and project champion.

The main conclusion of the authors is that all the 23 factors must be checked for at every review period to determine if they have changed significantly to make a project unattractive. They develop a simple decision rule based on the deterioration and improvement of a certain subset of these factors. For example, if a large number of selected factors weigh heavily against the project, then the project should be terminated. If the factors deteriorate but not to the extent of termination then the project should be shelved.

Bedell (1983) focused on R&D projects that are terminated prematurely because of the lack of technical progress, i.e., the projects are adequately funded and staffed, but failed to

achieve their technical goals within budget and schedule. In this conceptual study, Bedell developed a single model for both R&D selection and termination. The model views each project not as an entity along a single dimension, but within its relationship to the environment of the project. Thus, the internal and external environment are inputs to the project review and termination model in addition to purely technical considerations. The internal considerations include corporate goals and strategy, economic analysis, relationship to current and future products and to other R&D projects, project resources and alternative uses of project funds. External factors include competition, customers' desires, economic factors and government regulations. The view that a single model is applicable for both R&D selection and termination decisions was rejected outright by several authors (e.g., Balachandra) who argue that the selection decision is both conceptually and temporally different from the termination decision. Conceptually it is different because it involves a different set of issues and considerations and, temporally it is different because it occurs at a later and usually unspecified time.

Tadsina (1986) defined a terminated project as "one where the resources allocated to it have been withdrawn without the original objectives/purposes having fully been met" (p. 97). He developed an empirical discriminant function model which could be used to monitor the performance of projects. The input to the decision model are a set of factors associated with the success/failure of projects taken from a study by Baker et al. (1986). The analysis is based on a database of 220 projects from 21 firms in 4 lines of business: low carbon, flat rolled steel, agricultural chemicals, packaged processed foods and industrial chemicals. Data were gathered through interviews with senior officials in the participating firm. The sample consisted of both process and products as well as successful and failed projects. The success/failure category was based on the official's evaluation of the project and whether or not the project was terminated. Tadsina identified a set of 23 variables which he

grouped into 5 categories based on factor analysis. The categories of variables were project uncertainty at initiation, pressure to start project, expected impact, science and technology areas, and intention to protect project outcomes. The results indicate a lack of common determinants of R&D project success across different lines of business. This suggest that each organization may need its own specific database to account for nuances of organizational policies, procedures and strategies.

Balachandra and Raelin (1985) conducted an empirical study of 51 projects in high-tech companies in the U.S. The data was collected through two mailed interview schedules and two face to face interviews. The respondents were typically project leaders or R&D managers depending upon the instrument in use. The determination of "high-tech" status was made according to SIC classification. The data was analyzed using discriminant analysis. The factors influencing the continue or terminate decision fell into 7 main categories: strategic, economic, environmental, technological, operational, behavioral and organizational. The results showed that strategic and behavioral factors were the most important discriminating variables. Strategic variables such as high rates of product turnover, high market share and small size led to continuations, whereas infancy stage product life cycle and innovative versus aligned research strategy led to terminations. The controllable behavioral factors which were critical to project continuation included project management effectiveness, management support, worker commitment, and project leader championship during the projects later stages. In contrast to high tech firms, "non-high-tech" projects were found to have a greater potential where product turnover was low and projects had limited focused end uses offering sizable profit margins.

Shafer and Mantel (1989) developed a Decision Support System to assist in the termination decision. The model system includes a global database for specific projects, the

organization's internal and external environments, and a weighted scoring model. The system assigns scores, generated by the weighted scoring model, to each project. These scores are compared with certain thresholds to determine which projects are to be continued and which are to be terminated. The authors did not develop nor investigate any definitive set of success/failure criteria to be used in the model because they believed that the criteria differ for various industries and possibly for firms. The model was tested with only one hypothetical example.

2.5 Summary

In summary, it is clear from the preceding analysis that considerable diversity exists concerning the innovation process, the factors that determine the success and failure of innovations, and even the definition of success and failure. In addition, all of the termination studies, with the exception of Balachandra and Raelin (1980) and Tadsina (1986), failed to develop any systematic procedure to monitor the performance of projects which can be used for the termination decision. Moreover, almost every study on the success and failure of innovations, except for Pinto and Slevin (1989) and Pinto and Prescott (1988), analyzed the success/failure factors from a static point view. That is, they treated the factors that determine the success or failure of a project as being of equal and stable importance throughout the various stages of the innovation process. Even the elegant studies done by Tadsina (1986) and Balachandra and Raelin (1980) on the termination decision treated the factors this way. For example, Balachandra and Raelin (1980) suggested that "at the review period, it is proposed that the ongoing projects be reevaluated on the basis of the 23 factors presented". No mention is made of any subset of factors that is applicable to any particular stage of the innovation process at which the project resides. Tadsina (1986) also proposed that his index which measures the likelihood of success be computed for a project at different point over the life of the project.

However, this index of success is derived from all the success/failure factors utilized in his study. Thus, the success/failure factors are treated in much the same way as in most other studies. Only the studies by Pinto and Slevin (1989) and Pinto and Prescott (1988) linked the success/failure factors to the life cycle of the innovation project. Both of these studies reported evidence that the factors vary depending on the stage at which the project resides. In addition, the role, and consequently the weights of factors relevant to more than one stage varies in different stages.

CHAPTER 3

THE STUDY

3.0 Introduction

From the preceding review we observe that the only studies which link the success/failure variables to the stages of the R&D innovation process were done by Pinto and Slevin (1989) and Pinto and Prescott (1988). Pinto and Slevin used a four stage model of the innovation process. The stages were: conceptual, planning, execution, and termination. The two stages used by Pinto and Prescott were the tactical and strategic stages. It is suggested here that the four-stage and two-stage innovation process models used by Pinto and Slevin (1989) and Pinto and Prescott (1988) respectively are too general to be used for monitoring an innovation project. This is because these models do not capture sufficient details of the activities, processes and decisions involved over the life of a project. Further, there is no real justification for making the termination stage the last stage after execution since termination can occur before execution or at any of the other earlier stages. Despite these shortcomings, the studies provide a useful starting point for more rigorous analysis of the causes of project failure at various stages of a project.

This chapter provides a detailed description of the innovation process model used in the study, the research objective, the methodology, and the various analyses conducted.

3.1 Activity-Decision Stage Model

This study has attempted to develop a more detailed model of the innovation process to which the success/failure variables were linked and consequently a termination framework is developed. The model of the innovation process used in this study focussed on the activities and decisions involved at each stage of the innovation process. The model shown

in Figure 2 depicts the main activities and decision points involved in the process of developing a new product or process.

The activity-decision stage model in Figure 2 shows that a typical innovation passes through five stages - initial screening, commercial evaluation, development, manufacturing and marketing launch, and commercialization. The stages are indicated by the rectangular boxes. The type of activities corresponding to each stage is indicated by the ellipses. The overlapping ellipses indicate that the activities could either be conducted sequentially or concurrently and there could be a number of feedback loops among those activities. The small diamond-shaped boxes indicate a decision or review point. According to the model, there can be any number of decision points between any two consecutive stages depending on the nature of the project or firm. However, the project should not advance to the next stage without satisfying the conditions of the current stage. Projects which do not move to the next stage or are shelved are considered to have been terminated. The activities typical of each stage are described below.

3.1.1 Initial Screening

The activities of this stage are very preliminary and are less formal in nature. These are usually done within the department from which the idea for the project originated, and in some cases with assistance from R&D. The amount of resources committed to the project at this stage is meagre. Some of the typical activities of this stage include an assessment of the following:

- the market potential for the project.
- the technical feasibility of completing the project within a specified time frame
- the costs/benefits
- the compatibility of the project objectives with the firms goals and strategy.

FIGURE 2
Activity-Decision Stage Model of the Innovation Process

3.1.2 Commercial Evaluation

The analysis of this stage are more rigorous and formal. Also, more resources in terms of personnel, time and finances are allocated to the project. The activities typical of this stage include an assessment of the:

- potential market size
- price sensitivity of the market
- cost of production and other resource requirements
- total investment required for the project
- technical feasibility of completing the project within a specified time
- technology required for the project, its availability and the project workers' familiarity with it
- anticipated technical problems and the estimated time in which these can be resolved
- effect of the project on the firm's existing product line, and
- compatibility with the firm's goals and strategies.

3.1.3 Development

At this stage the firm's commitment to the project is substantial in terms of financial and personnel resources. The activities of this stage involve the following:

- draft and detailed designs, specifications, prototype development and prototype testing
- identify field test sites
- verify all operational specifications of the project
- determine whether reliability of specifications are satisfactory with adequate margins
- build first pre-production units and make necessary changes
- verify, update and produce documentation
- perform low level market test.

3.1.4 Manufacturing and Marketing Launch

At this stage the firm is fully committed to developing the project on a commercial scale. This stage requires that production facilities (plant, tooling etc.), personnel and financial resources are available in quantities that is needed for full scale commercial production. The activities at this stage involves developing tooling and full documentation for the product, producing the first batch of the product, and launching the product in the test market. Other activities which are important at this stage include the following:

- generate complete set of assembly/installation procedure
- develop marketing strategy - pricing, advertising, etc.
- identify distributors
- train sales force
- procure inputs and produce full production units

3.1.5 Initial Commercialization

This stage basically involves maintaining adequate supplies of the product in the market, providing after sales support and service, and ongoing monitoring of the product performance in the marketplace.

3.2 Success and Failure Variables

The success/failure variables considered in this study were drawn from the literature and from a survey of R&D managers. The success/failure variables relevant to each stage of the innovation process were identified by a combination of theoretical argumentation and statistical testing. The statistical technique of stepwise logistic regression was used to select variables at each stage. Having identified the variables relevant to each stage, the framework to monitor projects throughout their life times was developed.

The study focused on Canadian firms in the high technology industries such as transportation and aerospace, computers and office equipment, electrical equipment and components, medical equipment, machines, professional and scientific instruments, industrial chemicals, and radio and TV receiving equipment. The high-tech industries were selected because of the phenomenal rate at which new product development is taking place in these industries. Also, the number of successful and failed innovations are quite high in these industries (Maidique and Zirger, 1984) thereby providing ample scope for the study. Further, the very survival and competitive advantage of firms in these industries rests on their ability to successfully introduce new products and reduce the risk of failure. Therefore, a framework to identify problems with projects at an early stage will greatly reduce the time and cost of continuing a project beyond what is necessary. Finally, high-tech industries have been selected because of their importance to all aspects of human activity. Indeed, the very quality of our life is dependent on the continued technical progress in these industries.

3.3 Research Objective

The main objective of this study is to develop a framework to decide when to terminate an ongoing innovation project. The framework is based on the notion that the variables which affect the continue/terminate decision vary with the stages of the project.

3.4 Methodology

The study is based on a survey of firms in the high technology industry in Ottawa, Canada. The list of firms from which the sample was drawn came from a combination of three sources, namely, the Industry, Science and Technology Canada (ISTC) BOSS database, the Ottawa-Carleton Economic Development Corporation directory of high technology

firms and the Ottawa Citizen (March 5, 1992). All consulting and distributing firms as well as firms with less than forty employees were not considered for selection. Preliminary investigations revealed that most of the smaller firms did little or no R&D. From this list of 89 firms a sample of 45 high tech firms representing a diverse set of industries was randomly selected for the study.

The firms selected in the sample were contacted by telephone, and their participation in the study was sought. Thirty-six out of the forty-five firms contacted agreed to participate in the study. Twenty four of the respondents agreed to provide information on two projects (one success and one failure). Twelve firms provided information on only one project, ten cases of success and two of failure. In all, data was collected for a total of 60 projects of which twenty-six were failures and thirty four were successes. The main reasons for not participating given by the non-responding firms were as follows:

1. three firms claimed that they are in the defence industry and would not provide data to the public regardless of the purpose;
2. four firms claimed that they could only participate in the study until after the Summer or around mid-Fall, and
3. two claimed to have given considerable time to other Carleton University students in the recent past and were not in a position to entertain other requests at that time.

The data was collected through personal interviews using a structured interview schedule. The schedule was administered mainly to the head of R&D or Engineering or to a project leader in the company because the information requested required familiarity with the R&D projects. Each respondent was asked to list 3 or 4 innovations, including at least one failure, from which the researcher randomly chose one or two. Of the companies which

listed more than one successful innovation, one was selected randomly. Since most of the companies who listed failed projects offered information only on one failure, random selection of the failed project was not possible.

The data collection instrument was pretested on three firms. The firms in the pretest were asked to comment on the adequacy, relevance and clarity of the questions. The pretest exercise resulted in the deletion of two questions, the rephrasing of one, and the addition of another. The firms used in the pretest survey were included in the study because the changes to the data collection instrument were considered minor.

The interview schedule requested information about the company and the specific project chosen by the researcher. Specifically, the following information was requested: the company's level of sales, employment and profitability, industry grouping, size and structure of the R&D department, type of projects, financial information about the projects, factors responsible for the success and failure of the projects, how the decision to continue a project is made, and when was a failed project terminated, i.e., at what stage of the innovation process the failed project was stopped. The interview schedule used a combination of rating scales and open ended questions to obtain the information. Respondents were encouraged to discuss in more detail some of the rating scale questions in order to get a deeper understanding of their responses.

Table 3 summarizes some of the general characteristics of the participating firms of the study. The sample of firms consisted of 31 Canadian-owned and 5 foreign-owned firms. The average number of employees (EMPLOY91) is 165 with the number of R&D employees (RDEMPL91) averaging 23. The firms average annual sales (SALES91) is approximately \$125 million and their annual R&D budget (RDEXP91) is approximately

\$11.8 million or approximately 9.4% of sales. There were approximately seven active projects (PROJPORT) per firm at any point in time. The minimum number of active projects reported was three. The average expected market share (MKTSHARE) and the rate of return (RATERET) for the projects selected were 7% and 25% respectively.

Table 3
General Profile of Participating Firms

Variables*	Median	Minimum	Maximum	N
EMPLOY91 (#)	165	40	4500	36
RDEMPL91 (#)	23	3	40	36
SALES91 (mil)	125.0	1.0	850	36
RDEXP91 (mil)	11.8	1000	29000	33
PROJPORT (#)	7.0	3.0	40	35
MKTSHARE (%)	7	1	9	23
GPROFIT (%)	20	1	9	29
RATERET (%)	25	2	30	26

* See Appendix 1 for the definition of variables

3.5 Quantitative Model

The model in Figure 3 was derived from the activity-decision stage model described earlier in Figure 2. The model shows that projects could be classified into any one of the five mutually exclusive and exhaustive states: failed at stage 1, failed at stage 2, failed at stage 3, failed at stage 4, and a complete success. The X's shown in Figure 3 represent the set of variables relevant to the decision stage. Some of the individual variables may be relevant to more than one stage. It is possible that the quality of decision at one stage may affect the decision at a subsequent stage(s). This "carry over effect" is indicated by the broken arrow joining two consecutive decision stages. The broken arrow indicates that in this thesis, this effect will be modelled only through the inclusion of some common variables in the

FIGURE 3
Quantitative Model

Xi 'S = Variables relevant to each stage

D1 -D4 = Decision point (stages) corresponding to innovation process model.

variable sets relevant to each stage. Other detailed models of possible interplay between decisions can be developed; they are, however, beyond the scope of this investigation. The response variable of the stagewise logistic regression model consisted of all completely successful projects and only those projects that failed at a particular decision stage

3.6 Data Analysis

The data was analyzed using the statistical package SPSSPC+. Stepwise logistic regression was the principal technique for this analysis. The method of logistic regression was chosen because it is a natural technique to use in situations where the dependent variable is dichotomous, for example, continue or terminate as in this case, and the independent variables are continuous or categorical (including dichotomous). Generally, the logit of a multiple logistic regression model is given by the equation:

$$g(x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n$$

where $x_1, x_2, \dots, x_n$ represents the predictor variables.

The likelihood function is given by:

$$\pi(x) = 1 / [1 + \exp\{g(x)\}]$$

Where $\pi(x)$ = probability of success.

Hosmer and Lemeshow (1989, p.108) noted that a crucial aspect of using stepwise logistic regression is the choice of an "alpha" level to judge the importance of variables. This alpha level will determine how many variables will ultimately be included in the model. Hosmer and Lemeshow suggested that the generally used alpha level of .05 (5%) is too stringent because important variables could be left out of the model. They recommended an alpha level of between .15 to .20 (or between 15-20%). The larger the alpha, the easier it is for

variables to enter the function. In this thesis, the entry criterion was at .10 (or 10%).

It is noted that discriminant analysis is an alternative method for dealing with binary or dichotomous variables. In fact, discriminant analysis is the only multivariate method that has been used in the termination research to date. However, we have chosen the logistic regression method over discriminant analysis because the former requires less restrictive assumptions than does discriminant analysis. Discriminant analysis is based on the assumption that the distribution of independent variables, given the value of the dependent variable, is multivariate normal, an assumption which is not required in logistic regression. In fact, in this study the assumption of multivariate normality cannot be expected to hold because of the frequent presence of dichotomous predictor variables.

Serious violation of the normality assumption could present difficulties in analyzing and interpreting the results of discriminant analysis. Halpern, Blackwelder and Verter (1971) and Hosmer, Hosmer and Fisher (1983) compared the multiple logistic regression method with multiple discriminant analysis when the model contains a mixture of continuous and discrete variables. The authors found that the maximum likelihood coefficients from discriminant analysis are very sensitive to the assumption of normality. Also, the estimators of the coefficients for non normally distributed variables are biased away from zero which implies that for dichotomous independent variables, the discriminant function estimators will overstate the magnitude of the association. Hosmer and Lemeshow (1989) suggest that when normality is violated discriminant function estimators should only be used when logistic regression software is not available, and even then only in preliminary analysis. Any final analyses should be based on the maximum likelihood estimators of the coefficients.

The sampling plan used in this study resulted in 24 pairs of projects from 24 companies and 1 project from each of the remaining 12 companies. Thus, the individual projects cannot be regarded as a simple random sample from a universe of projects. The presence of pairs of projects from some companies is a possible complication, given that these paired projects could be correlated as a result of factors common to the sponsoring company. It is known (Hosmer and Lemeshow, 1989) that such correlations may, if large enough, seriously violate the simple random sample assumption on which standard logistic regression is based. Because of this potential problem, four different logistic regression analyses were run. These analyses, labelled A1 through A4, are described in the following sections.

3.6.1 Analysis A1

This analysis ignores correlations and uses all sixty (60) projects, 26 failures and 34 successes. All projects are treated as if they were randomly and independently drawn from a universe of projects. The response variable in this case is success versus failure.

3.6.2 Analysis A2

This analysis operates at the stagewise level, again ignoring correlations. All successful projects and only the projects which failed at a particular stage of investigation were included in the analysis performed for that stage. For example, all thirty four successful projects taken together with the projects that failed at stage-one formed the dataset for stage-one analysis. Similarly, all thirty four successful projects taken together with the projects that failed at stage two formed the stage-two analysis dataset. This procedure was repeated for stage-three and stage-four.

It is noted that analyses A1 and A2 are similar in the sense that they both used the same dataset and they both ignore possible correlations among projects from the same company. Because these analyses ignore possible correlations, it is possible that too many variables might enter the models, given that the effect of ignoring correlation is generally to inflate the apparent “importance” of individual variables (Thomas and Rao, 1988). However, this tendency will be common to both analyses A1 and A2, and therefore, a comparison of the results of analyses A1 and A2 will still be instructive.

3.6.3 Analyses A3 and A4

Analyses A3 and A4 are performed only as checks on the validity of analyses A1 and A2. They consider only the successful (24) and unsuccessful (24) projects of the 24 companies reporting both, one of each kind. As noted above, considering these 48 projects as independent projects in a standard logistic regression yields potentially biased results, owing to the possible correlations between projects from the same company. Analysis A3 which is run only as a benchmark, again proceeds as if the pairwise correlations are zero. Analysis A4, however, allows for the possibility of a non-zero correlation by performing the paired analysis described in Hosmer and Lemeshow (1989, pp. 190-192). This was effected via the software package SAS. A comparison of the results of A3 and A4 for the predictive variables provide some guidance as to the seriousness or otherwise of ignoring the pairwise correlations for this data set.

The results and findings of analyses A1 and A2 are presented and discussed in the next chapter. Results of analyses A3 and A4 are discussed in chapter 5, where the implication of a comparison of these analyses on the results of analyses A1 and A2 are discussed.

CHAPTER 4

RESULTS OF ANALYSES A1 AND A2

4.0 Introduction

SPSSPC+ logistic regression procedure generates the following output:

Log Likelihood Statistic

Goodness of Fit (Chi-Square)

Classification Table

Wald Statistic

Partial Correlation Coefficient, R

Model Chi-Square

Improvement

The meaning of each of the above statistic are briefly discussed below².

4.1 Model Assessment Framework

The likelihood ratio tests and classification tables are commonly used measures to assess how well the model fits the data. Likelihood ratio tests are generally converted to approximate chi-square tests, and a small, i.e., non-significant value of chi-square is consistent with good model fit. Conversely, a large chi-squared test value, with corresponding small p-value, will be indicative of poor fit. However, this statistic is generally not useful when the predictor variables are continuous. Alternatively, the classification power of the model can be used to gauge fit. A good model should generally result in a high percentage of the cases being correctly classified. The Wald statistic for each variable included provides a test of significance of the individual predictor variables,

² The following discussion are taken from the SPSSPC+ Advanced Statistics V. 4.0 manual.

i.e., the Wald test is used to test the hypothesis that the coefficient of an individual variable in the model is not significantly different from zero (0). The R statistic is used to indicate the level of partial correlation between the dependent variable and each of the independent variables in the model. The R statistic can range in value from -1 to +1. A positive value indicates that as the variable increases in value, so does the likelihood of the event occurring. A negative value indicates the opposite relationship. Small values of R indicate that the variable has a small partial contribution to the model. The model chi-square tests the null hypothesis that the coefficients for all of the terms in the model, except the constant, are 0. This is equivalent to the overall F test for regression. The Improvement measures the change in the log likelihood ratio chi-squared statistic between successive steps of building the model. It tests the null hypothesis that the coefficients for the variables added at the last step are 0. The improvement chi-square test is comparable to the F-change test in multiple regression.

4.2 Analysis of A1 Results

Table 4 present the results of the analysis where all 60 projects were treated independently and the dependent variable was taken to be overall success, versus failure at any stage. According to the likelihood ratio test and the goodness of fit statistic, the model fits the data well. Also, the model chi-square and improvement statistic show a similar picture. From the classification table it is observed that the model correctly classified 92% of the failed cases and approximately 94% of the successful projects. The overall percentage of projects correctly classified is about 93%. The Wald test indicate that the key variables that determine the success/failure of an innovation project are:

- number of ongoing projects at any point in time (PROJPORT)
- extent and quality of market research conducted (MKTRES)
- level of efficiency of the development process (DEVPROC)

- the extent to which the commercial and technical aspects of the project are coupled, (COMTEKFT) and
- the extent of the marketing effort (MKTEFORT).

Table 4**Results of Analysis A1**

	Chi-Square	Df	Significance
-2 Log Likelihood	10.59	51	1.000
Model Chi - Square	67.55	5	.000
Improvement	6.48	1	.010
Goodness of Fit	9.11	51	1.000

Classification Table for Successes and failures**PREDICTED**

Failed Projects	Successful Projects	Percent Correct
-----------------	---------------------	-----------------

OBSERVED

Failed Projects	23	2	92.00%
Successful Projects*	2	30	93.75%

* Three missing cases

Overall 92.98%

Variables in the Equation

Variable	B	S.E	Wald	Df	Sig	R
PROJPORT	-.235	.134	3.07	1	.07	-.117
MKTRES	-12.47	7.01	3.16	1	.07	-.122
DEVPROC	-5.66	3.02	3.50	1	.06	-.138
COMTEKFT	-2.79	1.45	3.69	1	.05	-.147
MKTEFORT	-2.54	1.34	3.61	1	.05	-.143
Constant	38.19	16.34	4.34	1	.03	

4.3 Analysis of A2 Results

4.3.1 Decision Stage 1

The results in Table 5 indicate that the model does fit the data quite well. However, it is noted that in the first stage that only 60% of the failed projects were correctly classified compared to 97% of the successful projects. Overall, the model correctly classified approximately 92% of the projects. The most significant variable in the model is the extent to which the project objectives fit into the organization's overall corporate philosophy and strategy (CORPFIT).

4.3.2 Decision Stage 2

The results of decision stage two analysis are presented in Table 6. Again the results indicate a good fit. The percentage of failed projects correctly classified was 75% relative to 97% for successful cases. The significant variables which entered the model are the ease with which the Science and Technology (SCITEK) for the project is available, the reaction of other groups in the organization (REACTION), the number of uses to which the product/process can be applied to (USES), and the technical capability of the firm (TEKCAPAB).

Table 5
Results of Stage-One

	Chi-Square	Df	Significance
-2 Log Likelihood	13.219	37	.9999
Model Chi - Square	16.652	1	.0000
Improvement	16.652	1	.0000
Goodness of Fit	13.403	37	.9999

Classification Table for Successes and failures

		PREDICTED		
		Failed Projects	Successful Projects	Percent Correct
OBSERVED				
Failed Projects	3	2		60.00%
Successful Projects	1		33	97.06%
				Overall 92.31%

Variables in the Equation

Variable	B	S.E	Wald	Df	Sig	R
CORPFIT	-2.60	1.06	5.99	1	.0144	-.3657
Constant	9.16	3.42	7.19	1	.0073	

Table 6**Results of Stage-Two**

	Chi-Square	Df	Significance
-2 Log Likelihood	13.311	37	.9999
Model Chi - Square	27.590	4	.0000
Improvement	4.794	1	.0286
Goodness of Fit	14.016	37	.9998

Classification Table for Successes and failures**PREDICTED**

	Failed Projects	Successful Projects	Percent Correct
OBSERVED			
Failed Projects	6	2	75.00%
Successful Projects	1	33	97.06%
			Overall 92.86%

Variables in the Equation

Variable	B	S.E	Wald	Df	Sig	R
SCITEK	1.20	.671	3.18	1	.074	.170
REACTION	-3.65	1.748	4.36	1	.036	-.240
USES	-3.37	1.525	4.97	1	.025	-.269
TEKCAPAB	-3.94	2.011	3.85	1	.049	-.212
Constant	25.47	11.68	4.75	1	.029	

4.3.3 Decision Stage 3

Table 7 presents the results of decision stage three. It is observed that the percentages of failed and successful cases correctly classified are approximately 90% and 94% respectively. The two main variables which entered the model are the level of efficiency with which the development process is conducted (DEVPROC) and the extent to which the commercial and technical characteristics of the project are coupled (COMTEKFT).

4.3.4 Decision Stage 4

The results of decision stage four are presented in Table 8. It is observed that although the likelihood ratio test and the goodness of fit statistic indicate a reasonably good model, the classification results were poor. In fact, the model was unable to correctly classify any of the failed cases. Also, the significance of the Wald test for the last variable is just above .10. These results may have been influenced by the extremely small number of failed cases in the sample for this particular model. The two variables which entered the model are the technical capability of the firm (TEKCAPAB) and the extent of the marketing effort (MKTEFORT).

Table 7**Results of Stage-Three**

	Chi-Square	Df	Significance
-2 Log Likelihood	11.09	40	1.0000
Model Chi - Square	35.54	2	.0000
Improvement	14.06	1	.0002
Goodness of Fit	12.21	40	1.0000

Classification Table for Successes and failures**PREDICTED**

	Failed Projects	Successful Projects	Percent Correct
OBSERVED			
Failed Projects	9	1	90.00%
Successful Projects	2	31	93.94%
			Overall 93.02%

Variables in the Equation

Variable	B	S.E	Wald	Df	Sig	R
DEVPROC	-3.80	1.49	6.49	1	.01	-.310
COMTEKFT	-2.65	1.14	5.40	1	.02	-.269
Constant	20.18	7.88	6.56	1	.01	

Table 8**Results of Stage-Four**

	Chi-Square	Df	Significance
-2 Log Likelihood	12.81	34	.9957
Model Chi - Square	8.00	2	.0183
Improvement	2.81	1	.0935
Goodness of Fit	16.23	34	.9957

Classification Table for Successes and failures

	PREDICTED		
	Failed Projects	Successful Projects	Percent Correct
OBSERVED			
Failed Projects	0	3	0.00%
Successful Projects	0	34	100.0
			Overall 91.89%

Variables in the Equation

Variable	B	S.E	Wald	Df	Sig	R
TEKCAPAB	-4.23	1.96	4.64	1	.03	-.356
MKTEFORT	-1.95	1.25	2.42	1	.11	-.141
Constant	8.25	3.87	4.54	1	.03	

4.4 Analysis A1 versus Analysis A2

As mentioned earlier, analyses A1 (the overall analysis) and analyses A2 (stagewise) are similar in terms of the treatment of the projects, i.e., in both analyses the sample observations were used as if they were independent units of analysis. However, in the stagewise analysis eight variables entered the model over the stages compared to only five in the overall analysis. The results therefore suggests that the stagewise analysis of projects gives wider coverage than the overall analysis. Consequently, a more detailed view of the project can be obtained as it moves through the various levels of development. Conversely, it is possible that important dimensions of the project may be excluded from the review process when the overall, rather than stagewise, analysis is used.

4.5 Explanation of Variables

In this section, the significant variables emerging from the stagewise level analysis are explained further, based on information provided by respondents. The explanation focuses on the dimensions of each variable and on how the variables can be measured.

The results of the stagewise stepwise logistic regression analysis revealed that there are eight major variables which are crucial over the life of the project. At the initial screening stage, the main variable is the extent to which the objectives of the project are congruent with overall corporate strategy and goals (CORPFIT).

At stage two, commercial evaluation, the main variables are the availability of and the familiarity with the science and technology underlying the project (SCITEK); reaction of other groups and individuals not directly associated with the project (REACTION), the number of potential applications of the project (USES) and the technical capability of the

firm (TEKCAFAB).

At stage three, development, the major considerations are the efficiency of the development process (DEVPROC) and the extent to which the commercial and technical aspects of the project are coupled (COMTEKFT).

At stage four, manufacturing and marketing launch, the two major variables that emerged were the level of the marketing effort (MKTEFORT) and the firm's technical capability (TEKCAPAB).

It is noted that several of the variables found to be important in earlier studies do not appear to be significant in this study. Some examples include defining and communicating the project mission; the existence of a project champion; the effect of government regulation; and certain financial variables such as, profitability, market share and return on investment (ROI). However, a closer examination of the data revealed that several of these variables had similar values for most projects. The lack of between project variability of these variables might have accounted for their poor performance. For example, over 85 percent of the projects had a project champion from the very beginning of the project; approximately 80 percent of the respondents indicated that the project mission was clearly defined and widely understood throughout the life of the project. Similarly, approximately 96% of the projects were not affected by government regulation. Whether or not this is an attribute of the data set is not clear. Further studies may clarify this point.

The failure of these variables to enter the model directly does not necessarily suggest that they are not relevant. On the contrary, the perceived importance attached to these variables by the firm can be gauged by the rating given to these variables in the interview. For

example, the perceived importance of a project champion can be observed from the fact that over 85 percent of the firms had a project champion from the very beginning. A similar observation can be made with respect to the project mission and government regulation. However, it is also interesting to note that a number of the failed projects also had a project champion from the beginning, the project mission was clearly defined from the start, and the government regulation had no negative effect on the project. This would suggest that although these variables may be important dimensions of the project, they may not be important for discriminating between success or failure.

The following section describes in greater detail the eight variables which emerged as significant in the stagewise analysis.

4.5.1 Corporate Fit

One of the major initial considerations in assessing a project is to determine whether or not the project objective is congruent with overall corporate goals and strategies. This involves the following:

- (a) establishing whether the project is a continuation of the company's existing product line or if it is a new idea which will take the company into new and untested waters. An important issue here concerns the effect of this project on the company's existing product line i.e., whether it enhances or decreases the viability of existing product line.
- (b) matching the resources of the company with the resource requirements of the project and determining any gaps,
- (c) determining whether the project can be completed within specified time and cost schedules, and
- (d) assessing the extent to which the project meets corporate marketability and profitability standards.

4.5.2 Science and Technology

The science and technology on which the project depends could be a major factor in determining the outcome of the project. Therefore, it is important that at the very early stages of the project the following dimensions of the science and technology are clearly established:

- (a) whether the science and technology which forms the foundation of the project is available within or outside the firm as well as its technical sophistication and extent of outside technological dependence,
- (b) the extent to which the project team is familiar with the underlying science and technology. Familiarity with the technology can be established by ascertaining the extent of practical experience of the project team with the technology and/or their knowledge of the technology. A related issue here concerns the relative newness of the technology. If the technology is relatively new then it may not have been in the marketplace long enough to be tested. Also, the available sources of information regarding the technology need to be identified. Information about the technology may be obtained from several sources outside the firm. The sources include published journal articles and books, trade fairs, and other firm's experience with the technology.
- (c) anticipated major technological problems associated with the development of the project and the time frame required to resolve these problems,
- (d) the development process using the technology and what additional manufacturing facilities are required and at what cost.

The decisions whether to develop the technology in-house or to sub-contract, purchase or license the technology are crucial considerations which may affect the delivery and consequently the success of the project. These considerations could have a significant

impact on the development time of the innovation and consequently on how early the technology is introduced into the marketplace. In fact, several firms still consider first to the market a big ticket item especially when the life cycle of a product is short. Also, an increasing number of firms engage in sub-contracting as a means to reduce development time, cost and risks.

4.5.3 Reaction

Unfavourable reactions from other groups, within the firm, not directly related to the particular project could have a negative impact on the project. This reaction may come from other project teams or influential individuals who feel threatened or feel that they were treated unfairly for whatever reason. Such reactions tend to affect the morale of the project team and could create an atmosphere of tension among team members. For example, if it is perceived that the project further an organization member's self interest then this could spur a chain of negative reactions leading to the demise of the project (Pinto and Slevin, 1989). The reaction of other groups and individuals within the company could be ascertained by the level of cooperation and interdepartmental communication in the organization and the degree of socialization of workers in the company. In this regard top management could play a significant role in fostering a cohesive atmosphere in the firm. In fact, a few respondents indicated very strongly that they have witnessed potentially good and promising projects being abandoned because of infighting and backstabbing among project teams and project leaders.

4.5.4 Potential Uses of the Project

The number of potential applications to which the innovation can be put to must be clearly defined. Intuitively, one can argue that the more applications to which the innovation can be put to the better the chances for its success. However, in the development phase this could

lead to constant changes in the design and specification which could lead to long delays and significant cost overruns in the development of the project. In establishing the potential uses of the innovation, it is necessary to establish the uniqueness and superiority of the project, the size of the potential market, the price range of the product and the responsiveness of the market to changes in price.

4.5.5 Firm's Technical Capability

The technical capability of the firm refers to the extent to which the firm's resources in terms of physical assets, personnel and finances are adequate to support the project. These resources include plant, equipment, tools, capable individuals with the necessary knowledge and expertise about the technology underlying the project, and access to finance capital. The firm's technical capability could be a very critical factor in resolving unanticipated technical problems especially in the development and testing stage or even after the project is commercialized. In fact, Cooper (1990) found that a low degree of technological synergy - a poor fit between the technological needs of the project and the R&D resource base of the firm - to be a major discriminating factor between success and failure of a project. The firm's technical capability can be determined by the number of workers in the firm with the requisite skills, experience and knowledge for the project. Also, by assessing the capability of the firm's physical assets to satisfy the demands for the project. Finally, determining whether the firm's internal funds and/or access to external funds are adequate to cover development, marketing, and distribution costs associated with the project.

4.5.6 Efficiency of the Development Process

Generally, the efficiency of the development process is expressed in terms of the time and cost involved in bringing the innovation to the marketplace. In this study more than 90% of the firms indicated that they rarely complete projects within the internally set time limit and

budget. Several explanations were advanced for the inability of the firms to complete the project within preset cost and time schedules. The major dimensions of efficiency of the development process include the following:

- (a) marked changes to the firms technical capability, for example, when one or more key project members leave the organization,
- (b) lack of commitment or low morale of project team. The commitment and morale of the project team could be assessed by observing the willingness of team members to work beyond the normal scheduled hours of work, the willingness to accept additional duties and responsibilities associated with the project, whether they talk about the project with interest or indifference, and the level of socialization of the project team.
- (c) observable shifts in top management support. Top management support can be gauged by their willingness to expedite at short notice requests for additional resources, the frequency of visits to the project site, frequency of informal meetings with project workers, and the degree of access of the project leader to the firm's top executives.
- (d) unforeseen technical problems which could not be resolved quickly,
- (e) unavailability or difficulty in acquiring certain critical component,
- (f) errors in the design or prototype phase,
- (g) poor communication and coordination of project activities among various departments, and
- (h) lack of adequate troubleshooting procedures.

4.5.7 Commercial and Technical Coupling

Effective coupling of the commercial and technical aspects of the project is critical for the success of a project. Incorporating user requirements into the project could greatly reduce the barriers to market acceptance. Effective coupling requires a clear understanding of who are the potential users, the potential number of applications of the project, the technical,

physical and other features of the project as well as the cost of production, price elasticity, and the time required to deliver the project. In essence, the technological prowess of the firm must be reinforced with a strong market orientation, emphasis on market based idea generation, search for a product with differential advantage and a willingness to accept risks (Cooper, 1990). In fact, a certain company had developed a very sophisticated telecommunication equipment for industrial users which was not accepted by users since it was physically too big in spite of the fact that its technical capabilities were according to expectations. It took the company approximately two additional years to redesign and re-develop the product according to users requirements.

4.5.8 Marketing Effort

The extent of marketing proficiency can be a critical factor in getting market approval of the project. Marketing proficiency refers to the extent and intensity of the marketing activities, educating and possibly training users regarding the uses and benefits of the project, training of sales force, after sales support and service arrangements.

4.6 Summary of Results

The preceding statistical analyses identified the major dimensions of project performance which discriminate between successful and failed projects. The stagewise analyses revealed that there are eight major variables which are indicative of project success. The dimensions of each of the variables were described in greater detail. Finally, it was noted that the stagewise analyses of projects tend to give a wider coverage of various dimensions of a project than does an overall analysis that essentially combines all stages into one.

CHAPTER 5

RESULTS AND IMPLICATIONS OF ANALYSES A3 AND A4

5.0 Results of Analyses A3 and A4

The first part of Table 9 shows the results of the analysis of the 48 projects (24 successful and 24 failed) treated independently, i.e., ignoring possible correlations within company. The last two lines of Table 9 shows the results of the Hosmer and Lemeshow analysis, which takes account of the pairing. In this analysis two variables “efficiency of development process” (DEVPROC) and “workers commitment” (WOKCOMIT), entered the model via stepwise regression. However, in the analysis which accounts for the pairing, only one variable, DEVPROC, entered the model via stepwise regression. Therefore, to make the appropriate comparison, the variable WOKCOMIT was forced into the paired analysis. The results of these two analyses, A3 and A4 with WOKCOMIT forced into the model, indicate that the signs of the coefficient estimates are similar for both variables in both analyses. However, the magnitude of the coefficient estimate of the variable WOKCOMIT as well as the standard error obtained from the paired analysis are different from the analysis which ignores pairing. If the variable, WOKCOMIT, is dropped from the analysis, the results obtained for the sole variable, DEVPROC, is very similar to the analysis which ignores the pairing.

5.1 Implications of A3 and A4 Results

These results clearly indicate that there is a difference in the two analyses, A3 and A4, i.e., that the pairing does have an effect and therefore the pairwise correlations cannot be ignored. The fact that the paired analysis with the variable DEVPROC alone gives results more similar to the analysis which ignores the pairing, i.e., analyses A3, suggests that maybe only DEVPROC should have been admitted into analysis A3.

As mentioned earlier, ignoring possible correlations could allow some variables to enter the model which might otherwise not entered the model. The preceding analysis would support this argument. Therefore, it may be necessary to make some adjustment for the effect of the pairing on the results. One crude method that can be used for adjusting for this effect is to set a more stringent entry significance level for variables to enter the model. For example, instead of using the traditional 5% level, an entry level of 1% or 2% could be used. In the case of analyses **A3** which ignores the pairing, applying an entry significance level of 2% would result in only one variable entering the model, instead of two variables.

5.2 Re-examination of Analyses A1 and A2 Results

This section will briefly re-examine the results of analyses **A1** and **A2** using the adjustment technique described above, with an entry significance level set at 2%. Applying this criterion to analysis **A1** would result in only two variables in the model, instead of five. For analysis **A2**, the variables entering the model at stages 1 and 3 remain unchanged. However, for stage 2 only one variable would have entered the model instead of four, and for stage 4 only one variable would have entered the model instead of two.

It should be noted that the results of the above analysis of the pairing are by no means conclusive, and should be interpreted with caution. Further research using a larger sample, i.e., more companies and more projects, coupled with a detail statistical analysis (using the approach of Binder (1983)) is needed to establish more concretely the effect of multiple projects per company on the analysis. Although the crude adjustment resulted in a reduced number of variables in the models, the results of analyses **A1** and **A2** could be interpreted directly, with some caution. Further, the results still confirm the earlier substantive conclusion that more variables are included in the stagewise approach (**A2**) than the overall

approach (**A1**).

Table 9

Results of Analysis A3 and A4

	Chi-Square	Df	Significance
-2 Log Likelihood	25.74	45	.9906
Model Chi - Square	40.80	2	.0000
Improvement	6.24	1	.0125
Goodness of Fit	58.45	45	.0861

Classification Table for Successes and failures

		PREDICTED		
		Failed	Successful	Percent Correct
		Projects	Projects	
OBSERVED				
Failed Projects	21	3		87.5%
Successful Projects	0	24		100%
				Overall 93.75%

Variables in the Equation

Variable	B	S.E	Wald	Df	Sig	R
DEVPROC	-1.54	.612	6.27	1	.012	-.253
WOKCOMIT	-1.55	.770	4.05	1	.044	-.176
Constant	7.85	2.09	14.0	1	.000	
DEVPROC*	-1.83	1.39	1.72	1	0.19	
WOKCOMIT*	-0.26	1.24	0.04	1	0.83	

* Results of the Hosmer and Lemeshow analysis (from SAS³).

³. B = -2.08

S.E = 0.846

Wald = 6.06

Sig = 0.013

5.3 Summary

This chapter examined the effects of possible correlations resulting from using paired data. The results suggest that if the correlations or pairing are ignored, there is a risk that some variables may enter the model which would otherwise not have entered. The crude correction strategy suggests that three variables too many may in fact have been included in the original stagewise analyses.

CHAPTER 6

THE MONITORING FRAMEWORK

6.0 Preamble to the Framework

Besides collecting the data on which the preceding formal analysis has been based, respondents were asked to describe how the decision to continue or terminate a project is made in their company and who are the major players in the decision making process. This section provides a summary of this qualitative data, which constitutes a description of the current procedures in practice in high-tech industries. The process is similar in most companies except that it is less formal among smaller companies. The status of the project is subject to periodic reviews during the life of the project. The frequency of reviews vary according to the length of the project, the size of the project in terms of investment, the importance and the urgency of the project and how the project is progressing. The majority of the reviews are conducted during the development stage. The decision to continue or terminate the project is based on the information provided by the R&D manager as well as top management's own experience. Although in most companies a unanimous decision is preferred, a majority decision is usually enough to decide whether the project should be continued or stopped. A typical review "team" consists of the firm's top executives, R&D Manager and departmental managers.

The respondents were also asked to state the number of reviews conducted at each stage of the innovation process and the factors checked for at each review. For convenience and simplicity, the innovation model developed in this study (Shown in Figure 2) was explained to the respondents and they were asked to answer in context of this model. Typically, the distribution of the number of reviews over the various stages were as follows:

Screening and Commercial Evaluation	1-2
Development	6-8
Manufacturing and Marketing Launch	3-5
Initial Commercialization	Ongoing

The set of factors monitored by the project team at each of the above stages are listed in Appendix 4.

Generally, most firms require that a detailed business case or business analysis be done before a project is approved for development. The business case/analysis is reviewed by the R&D manager or a person of equivalent status who will then pass it on to the top management for review. The business case is assessed against company's preset criteria on several project indicators. These indicators which include return on investment, profitability, market share, etc., reflect the market potential of the innovation as well as the feasibility of developing the innovation within some specified time frame. It is not unusual for the business case to go through several reviews before it is finally accepted. Once the project is accepted for development, milestones are set for all activities related to the project.

The reviews over the life of the project focus on two main set of factors. The first set of factors concern the continued market potential of the project as well as its resource requirements. The second set of factors focus more on the operational aspect of the project such as design and specifications, technical characteristics, communication, and meeting time and cost schedules. In some companies, the review process is quite elaborate. In these companies every activity is specified in great detail, the departments or individuals responsible for performing various activities are identified, and the timing and the form in which the progress reports should be presented to the firm's "review committee" are clearly

specified.

The decision to continue or stop a project is based on a comparison of the project's performance against the targets set for a number of indicators in isolation (or in a univariate fashion). This monitoring approach, however, could lead to faulty interpretation especially when there are conflicting signals from different indicators. Since the failure or success of a project depends on a number of factors, the most logical approach should then be to assess the combined effects of these factors in a multivariate or integrative fashion. The multivariate approach to analyze project's success is a very powerful methodology for assessing the partial effects of each variable as well as the possible interaction effects among variables (see Beaver, 1966 for a detailed exposition on this issue in the context of bankruptcy prediction).

6.1 The Framework

The remainder of this chapter discusses the monitoring framework developed in this study. For a monitoring framework to be of any practical use, and for it to be adopted by any organization, it must be systematic, reliable, cost-effective, easy to use and easy to manage. Further, it should be designed to foster creativity and complement managerial judgement by reducing uncertainty in decision making through a systematic, structured and improved information base. The utility of any monitoring framework depends to great extent on the information fed into it.

The framework in this thesis is based on an application of the results obtained from the stagewise logistic regression analysis, used in a predictive mode. However, to use the logit functions derived for each stage in the predictive mode, some adjustment to the intercept term is necessary because the proportion of successes in the sample is not equal to the

proportion of successes in the population⁴. The procedure used to statistically adjust for the bias in the constant term is described in Hosmer and Lemeshow (1989, p. 179-181). The adjustment procedure used in this study is described in detail in Appendix 3.

With the stepwise logistic regression procedure, the factors with the most explanatory power enter the logit function sequentially. Thus, it is a very powerful technique for deriving the most parsimonious model without losing any information. As mentioned earlier, because stepwise multiple logistic regression measures the combined effects of each variable on the outcome variable simultaneously, only those variables having the greatest joint predictive power remain in the model. This does not necessarily imply that the variables which do not enter the final model are not important. The implication for omitted variables is that they do not contribute any additional information over and above that already contributed by the variables already included in the model.

The major strengths of the logistic regression approach are that it is relatively simple to use, it avoids the problem of setting individual thresholds for each variable, and it provides an overall measure of the riskiness of the project.

In the stagewise stepwise logistic regression analysis used in this study, a separate logit function was derived for each stage. The probability function derived from the analysis at each stage measures the probability of the project success at that stage. The predictor variables in the model are usually referred to as the risk factors since they measure the "risk" associated with the project outcome. The values of the risk factors of the new project will be

⁴. To use Logistic Regression for prediction, it is required that the proportion of successes and failures in the sample be proportional to that of the population. If this assumption is violated, the constant term will be biased. Since the sample was not selected in proportion to the population, an adjustment is necessary.

set by management, based on details collected during the project review.

The general procedure for monitoring projects is suggested as follows: Take the logit function derived from the analysis for each stage and plug in the values of each variable of the new project into the probability function. The probability of success, π , is then derived by using the likelihood function

$$\pi_{\text{new}} = 1/(1 + e^{Y_{\text{new}}}),$$

where $e^{Y_{\text{new}}}$ is the exponent of $Y = \beta_0 + \beta_1 x_1 + \dots + \beta_n x_n$ for each stage.

The probability estimates for the new project, π_{new} , is compared to the preset, π_c , using the following decision rule:

IF $\pi_{\text{new}} > \pi_c$, project is likely to be successful, so continue project,

IF $\pi_{\text{new}} \leq \pi_c$, project is likely to fail, so terminate project.

6.2 Operationalizing the Framework

The following hypothetical example is used to illustrate how this approach can be operationalized:

In this example, the cutoff probability, π_c , is set at 0.5, i.e., a project with a probability score greater than 0.5 is likely to be successful, and conversely, a score of 0.5 or less is likely to fail. The cutoff probability level of 0.5 assumes that management is risk neutral.

The linear function⁵ for stage 1 after adjusting the intercept term is:

$$Y = 12.12 - 2.60(x)$$

where x = the value of the variable CORPFTT. Assuming that at the outset the variable was

5. The functions are obtained from Tables 5, 6, 7 and 8

assigned a rating of 5 because of initial optimism about the project, then the probability function yields a score of

$$\pi = 1/(1 + e^{-0.88}) = 0.70$$

However, at the first review, if the variable was assigned a lower rating of say 3 because of additional information, the probability of success would have been 0.15 indicating that the project is likely to fail and should be terminated.

At stage two, suppose the logit function is given by:

$$Y = 12.12 + 2.60(x_1) - 3.65(x_2) - 3.37(x_3) - 3.94(x_4)$$

where $x_1 = \text{SCITEK}$ $x_3 = \text{USES}$
 $x_2 = \text{REACTION}$ $x_4 = \text{TEKCAPAB}$

Assuming an optimistic rating of 4 for each variable yields a probability score of 0.99 for π . This means that the project is expected to be a definite success. However, if at a subsequent review, the rating given to the variables, REACTION and TEKCAPAB, was lowered to 2 and 3 respectively because of new developments, then the probability of success, π , changes from 0.99 to 0.46 indicating that the project is in trouble and is unlikely to succeed unless the situation changes.

Similarly, for stage 3 the logit function is given by:

$$Y = 20.18 - 3.80(x_1) - 2.65(x_2)$$

where $x_1 = \text{DEVPROC}$

$x_2 = \text{COMTEKFT}$

Assuming a rating of 4 for each variable, the probability of success, π , is 0.96 indicating high chances of success. However, if at the second review at this stage, the variables were given a rating of say 3, the probability of success changes to 0.40 indicating that the project is in trouble and is likely to fail.

For stage 4 suppose the logit function is given by:

$$Y = 8.25 - 4.23(x_1) - 1.95(x_2)$$

where $x_1 = \text{TEKCAPAB}$

$x_2 = \text{MKTEFORT}$

Assuming a rating of 4 for both variables yields a probability of score of 0.90. If the ratings for the variables were to be reduced to say 2, the probability score would fall 0.65; the project is likely to succeed.

6.3 Summary

The monitoring framework developed is based on the multivariate logistic regression methodology utilized in this study. The monitoring framework was described in detail and a hypothetical example was used to illustrate how the framework can be used. The major strength of this methodology is that it is simple to use, flexible, and it avoids many of the limitations of the traditional univariate approach. Finally, because it provides a single measure of the riskiness of a project, there is no need to set threshold levels for individual variables.

BENEFITS OF STUDY

The framework derived from the study is another useful tool which R&D managers can use to monitor projects within their company. The framework is simple to use, easy to manage, and flexible enough to incorporate the individual characteristics of firms and projects. The methodology on which the framework is based represents a major refinement over earlier frameworks which are based on univariate analyses and/or techniques which require very restrictive assumptions which are unlikely to be met in reality (e.g., Multiple Discriminant Analyses). For the firm, the framework could be a useful tool to identify problems with projects at an early stage so that appropriate corrective actions can be taken. This can result in considerable financial benefits in terms of reducing costs by not running project longer than necessary and consequently lead to more effective resource allocation. From an academic standpoint, the study provides the basis for more rigorous research and analysis of the issues discussed.

LIMITATIONS

The two major limitations of this study are the small sample size and the complex nature of the sampling plan. A larger sample of companies would allow for a standard analysis based on one project per company. Alternatively, a larger sample composed of the same number of companies, but more projects per company, would allow for an analysis based on modern methods for analyzing complex survey data. Due to practical limitations of cost and time, the present study falls between these two ideals. A corollary of small sample size is low statistical power to detect important variables. Despite these limitations, a cautious interpretation of the findings of this study has yielded meaningful results.

CONCLUSION

From the review of the project management literature, little research was found that focusses on the monitoring of innovation projects, in particular, on how projects should be monitored and when the decision to stop an ongoing project should be taken. This thesis concluded that the project termination decision is conceptually and temporally different from the project selection decision. Consequently, a methodology to monitor projects over their lives was developed.

The study was based on a sample of thirty-six high technology firms from a wide number of industries in Canada. The statistical method of stepwise logistic regression was the principal data analysis technique used in the study. The thesis identified eight major factors which discriminate between the success or failure of a R&D project over the life of the project. It was found that a stagewise analysis of projects provided significantly wider coverage in terms of the dimensions of the projects to be monitored than an overall analysis of individual projects where the stages are ignored. Based on the results of the stagewise analysis, a monitoring framework was developed and illustrated. Several advantages of the proposed framework over existing frameworks were discussed.

APPENDICES

APPENDIX 1

Definition of Variables

COMPID	COMPANY NAME
SUCFAIL	EITHER SUCCESSFUL OR FAILED PROJECT
STGFAIL	STAGE AT WHICH THE PROJECT FAILED
INDUSTRY	INDUSTRY GROUP OF COMPANY
OWNER	FOREIGN OR CANADIAN OWNED
EMPLOY91	NUMBER OF EMPLOYEES IN 1991
SALES91	SALES IN MILLION OF DOLLARS IN 1991
RDEMP91	NUMBER OF R&D EMPLOYEES IN 1991
RDEXP91	R&D BUDGET FOR 1991 IN \$000
PROJPORT	NUMBER OF PROJECTS IN PORTFOLIO FOR 1991
NPROFIT	NET PROFIT FOR 1991 IN PERCENT
DATSTART	DATE THE PROJECT STARTED
DATEND	DATE OF FINAL REVIEW OF THE PROJECT
PROJTYPE	NEW PROD/PROC OR SIGNIFICANT MODIFICATION TO AN EXISTING PRODUCT/PROCESS
MKTSHARE	EXPECTED ANNUAL MARKET SHARE OF THE INNOVATION
GPROFIT	EXPECTED GROSS PROFIT AS PERCENTAGE OF SALES
RATERET	EXPECTED ANNUAL RATE OF RETURN
SUCCESS	EXPECTED PROBABILITY OF ACHIEVING SUCCESS AS DEFINED BY CORPORATE OBJECTIVES
TEKROOT	PROBABILITY OF COMPLETING PROJECT UNDER ORIGINALLY DESIGNATED TECHNOLOGICAL ROUTE
CHAMPION	EXISTENCE OF A PROJECT CHAMPION

CHAMPSTG	STAGE OF THE PROCESS WHEN PROJECT CHAMPION EMERGED
SUCCRATE	ESTIMATE OF SUCCESS RATE OF NEW PRODUCT INTRODUCTION BY THE COMPANY
MISSION	PROJECT MISSION CLEARLY DEFINED FROM START TO END
CORPFIT	CLOSE FIT BETWEEN CORPORATE & PROJECT OBJECTIVES
SCITEK	EASY ACCESS TO SCIENCE & TECHNOLOGY
DEVPROC	DEVELOPMENT PROCESS WAS CONDUCTED EFFICIENTLY
TEKCAPAB	TECHNICAL CAPABILITY OF THE FIRM WAS ADEQUATE TO SUPPORT COMPLEXITY OF PROJECT
XPERTISE	TECHNICAL EXPERTISE READILY AVAILABLE WITHIN FIRM
COMTEKFT	COMMERCIAL AND TECHNICAL ASPECTS WERE VERY COUPLED
INTTEK	TECHNOLOGY FOR THE PROJECT CAME FROM WITHIN FIRM
COMPETE	MARKET FOR THE PROJECT IS HIGHLY COMPETITIVE
MKTRES	EXTENSIVE MARKET RESEARCH CONDUCTED
USER	USER NEEDS CLEARLY INVESTIGATED & UNDERSTOOD FROM BEGINNING
MKTEFORT	STRONG PROMOTION/SELLING ACTIVITIES WERE CONDUCTED
IDEA	IDEA FOR PROJECT CAME FROM WITHIN THE FIRM OR INDUSTRY
COMMUNE	GOOD EXTERNAL & INTERNAL COMMUNICATION WAS MAINTAINED THROUGHOUT THE PROJECT
COORDIN	COORDINATION BETWEEN MARKETING, PRODUCTION AND R&D WAS STRONG THROUGHOUT THE PROJECT

SUPPORT	TOP MANAGEMENT SUPPORT WAS STRONG THROUGHOUT THE PROJECT
WOKCOMIT	PROJECT WORKERS WERE STRONGLY COMMITTED TO THE PROJECT
REACTION	OTHER GROUPS WITHIN FIRM ACTIVELY SUPPORTED THE PROJECT
REGULATE	GOVT REGULATION HAD A NEGATIVE EFFECT
USES	INNOVATION PROVIDE USES NOT PREVIOUSLY OBTAINED FROM SIMILAR OR SUBSTITUTE PRODUCTS

APPENDIX 2

Interview Schedule

BACKGROUND COMPANY INFORMATION

1. Company name: _____
2. Name of respondent (optional): _____
3. Position: _____
4. Industry of company: _____
5. Is your firm Canadian owned? yes no _____
(Country of Ownership)

6.(a) Please indicate the following information for 1991, estimating where necessary (if you prefer, indicate the range):

- No. of employees: _____
No. of R&D employees: _____
Sales (in millions): \$ _____
R&D budget (in '000) : \$ _____
No. of projects in portfolio: _____
Net Profit as percent of sales: _____%

PROJECT INFORMATION

1. Date project started: _____
2. Date of final review: _____
3. Did the project result in:
new product new process
significant modification to an existing product
significant modification to an existing process
modest modification to an existing product
modest modification to an existing process

4. Please indicate the number of reviews conducted and the factors checked for at each of the following stages of the development process of this project:

<u>Stages</u>	<u>No. of Reviews</u>	<u>factors checked for</u>
A. Initial Screening	-----	-----
B. Commercial Evaluation	-----	-----
C. Development	-----	-----
D. Manufacturing & Marketing Startup	-----	-----
E. Commercialization	-----	-----

5. (Only for failed projects) Please indicate at which stage the project was terminated _____

6. Describe in your own words why this project was continued or terminated _____

7. Please describe how the decision to continue or terminate a project is made: _____

8. Who are the major players in this decision process? _____

9. For this product, what was the expected

annual market share? -----%

gross profit margin (as percent of sales)? -----%

annual rate of return (e.g., ROI, ROE etc.)?⁶ -----%

10. At the time the project started, what was the probability that this product would achieve commercial success as defined by corporate objectives? -----%

11. At the start of the project, what was the probability that the project would be completed under the originally designated technological route? _____%

12. (a). Did any one person emerge during the life of the project who became identified with it and who championed its cause? Yes No

(b). If yes, at what stage did that person emerge? _____

⁶ROI = Return on Investment

ROE = Return on Equity

13. For each stage, please indicate the percentage of times the project met its cost and time schedules (say within plus/minus 5%), and the reasons for not meeting these schedules.

<u>Stages</u>	<u>%Time</u>	<u>%Cost</u>	<u>Reasons</u>
A. Initial Screening -----			
B. Commercial Evaluation -----			
C. Development -----			
D. Manufacturing and Marketing Startup -----			
E. Commercialization -----			

14. Previous research estimate the success rate of new product/process introduction at about 10-12%. What would you say is the success rate in your company?-----%

15. Please indicate the extent to which the following description fits this project. Rate each of the statements on a scale of 1 (strongly agree) to 5 (strongly disagree). Circle the appropriate number.

	Strongly agree	Strongly disagree
(a) Project mission was clearly defined and recognized from start to end of project	1-----2-----3-----4-----5	
(b) There was a close fit between corporate objectives and project objectives	1-----2-----3-----4-----5	
(c) The Science and Technology for this project was easily available outside the firm	1-----2-----3-----4-----5	
(d) The development process was conducted efficiently	1-----2-----3-----4-----5	

- (e) Firm's technical capability was adequate to support the technical complexity of project 1-----2-----3-----4-----5
- (f) The technical expertise needed for the project was readily available within the firm 1-----2-----3-----4-----5
- (g) The degree of association between its commercial and technological aspects were very coupled 1-----2-----3-----4-----5
- (h) The technology for the project came from within firm 1-----2-----3-----4-----5
- (i) The market for this product is highly competitive 1-----2-----3-----4-----5
- (j) Extensive market research was done for the project 1-----2-----3-----4-----5
- (k) User needs were clearly understood from the beginning 1-----2-----3-----4-----5
- (l) There was strong promotion/selling for this project 1-----2-----3-----4-----5
- (m) The idea for this product came from within the industry not from users 1-----2-----3-----4-----5
- (n) Good internal and external communication was maintained throughout the project 1-----2-----3-----4-----5
- (o) Coordination between Marketing, Production and R&D was strong 1-----2-----3-----4-----5
- (p) Top management support was very strong throughout 1-----2-----3-----4-----5
- (q) Project workers were strongly committed to the project 1-----2-----3-----4-----5
- (r) Other groups within the firm reacted favourably and actively support project 1-----2-----3-----4-----5

PM-1 3 1/2"x4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

(s) Government regulation/patents had a negative effect 1-----2-----3-----4-----5

(t) The product provided other benefits/uses which other
existing or substitute products did not provided 1-----2-----3-----4-----5

Please make any other comments if you wish:

Would you like to have a copy of the final report mailed to you? Yes No

END OF INTERVIEW

Thank you very much for your time and willingness to participate in this study.

APPENDIX 3

Adjusting the Constant Term

The following procedure was used to adjust for the bias in the intercept terms for each of the four logit functions corresponding to the four stages of the analysis.

Step 1: Determine the probability of selecting a successful project i.e.,

$$\pi_s = \text{number of successes selected} / \text{total number of successes in population of successes or } \#s / \#s_p$$

Step 2: Determine the probability of selecting a failed project i.e.,

$$\pi_f = \text{number of failures selected} / \text{total number of failures in the population of failures or } \#f / \#f_p$$

Step 3: Determine the ratio π_s / π_f , i.e.,

$$\pi_s / \pi_f = \{ [\# \text{ of successes selected} / \# \text{ of failures selected}] / [\text{total } \# \text{ of successes in population of successes} / \text{total } \# \text{ of failures in the population of failures}] \} \text{ or } [(\#s / \#f) / (\#s_p / \#f_p)]$$

Step 4: Determine the quantity $\ln[\pi_s / \pi_f]$ and add it to the intercept term, β_0 , for each function of the four stages.

In Summary, the adjustment formula is

$$\ln[(\#s / \#f) / (\#s_p / \#f_p)] + \beta_i \quad \text{where } i = 1, \dots, 4$$

Since the questionnaire did not request information on the population of successes and failures *directly*, the number of projects in the firms portfolio is used as a proxy. However, the questionnaire requested that the respondent estimate success rate of new product introduction in the firm, p_i . Therefore,

$$s_p = \sum_i [(\text{\# of project in portfolio})_i (p_i)] / \sum_i [(\text{\# of project in portfolio})_i], \text{ and } s_f = 1 - s_p$$

From the data $s_p = .26$ and $1 - s_p = .74$

For stage 1, the ratio of number of successes to failure was $34/5 = 6.8$, thus,

$$\ln[6.8/(.26/.74)] = 2.96, \text{ and the adjusted intercept, } \beta_0, \text{ for stage 1 is } 2.96 + 9.16 = 12.12$$

For stage 2, the adjusted intercept, β_0 , is

$$\ln[4.25/(.26/.74)] = 2.49 + 25.47 = 27.96$$

For stage 3⁷, the adjusted intercept, β_0 , is

$$\ln[3.3/(.26/.74)] = 2.24 + 20.18 = 22.42, \text{ and}$$

For stage 4, the adjusted intercept, β_0 , is

$$\ln[11.33/(.26/.74)] = 3.47 + 8.25 = 11.72$$

7. There was one missing case.

APPENDIX 4

Dimensions of Firm's Review Process

The factors checked for at each stage are as follows:

Screening and Commercial Evaluation:

Project Objectives

Manufacturing Assessment

manufacturing facilities, tools, equipment,
personnel and other resource requirements

Market Assessment

market size, price, competitor analysis

Financial Evaluation

budget estimates, profitability, return on
investment, market share

Development:

Design and Specification

Prototype Development

Cost and Time Schedules

Documentation

Full Production Run

Coordination of Project Activities

Manufacturing and Marketing Launch

Specifications - design, quality, users needs,

Performance - field trials, test runs

Market, Pricing, and Advertising Strategies

Distributor Sales and Sales Support Training

Sales Support Strategy

Initial Commercialization:

Continuous monitoring of the product in the market in terms of customer satisfaction and/or complaints, sales volume, pricing, promotional strategy, customer support and service requirements, and when to enhance the product or take the product off the market.

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