HICKLING

FEASIBILITY STUDY OF A NATIONAL HIGH SPEED COMMUNICATIONS NETWORK FOR RESEARCH, DEVELOPMENT AND EDUCATION

VOLUME B: ECONOMIC ANALYSIS

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In association with:

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NOTE

This is Volume A of a study prepared by James F. Hickling Management Consultants Ltd. (HICKLING) on behalf of Industry Science and Technology Canada (ISTC), entitled "Feasibility Study of a High Speed Communications Network For Research, Development and Education". There are five volumes in this study:

1. Main Report
2. Volume A: Participant Needs
3. Volume B: Economic Analysis
4. Volume C: Technical Analysis
5. Volume D: Implementation Analysis

PREFACE

This study was commissioned by Industry, Science and Technology Canada to investigate the feasibility of establishing a National High–Speed Communications Network for the Canadian research, development and education communities. The network would have greater capacity and functionality than existing networks. While the undertaking of this study is not to be construed as a commitment by the federal government to the establishment of a network, the study will provide a solid basis for such an initiative should it be found prudent.

HICKLING is indebted to Dr. Digby Williams, Director, and Joseph Padden and Rafiq Khan, Senior Technologies Advisors, of the Microelectronics Technology Office, Information Technologies Industry Branch, Industry, Science and Technology Canada, for their expert technical and managerial advice in the conduct of this study. The authors would also like to offer thanks to the more than 400 individuals who participated in expert panel sessions, in–person interviews, and surveys; the study would not have been possible without their input. Of course, any errors or omissions are the sole responsibility of HICKLING.

The report was authored by David Arthurs, Phil Kennis, and Daniel Hara of HICKLING undet the direction of Dr. Verne Chant; and Roger Choquette and Antony Capel of COMGATE. Significant contributions were made by Dr. Saul Greenberg of the Alberta Research Council; Dr. Frederick Eshragh, Dr. Kalman Toth, and Dr. Samy Mahmoud of CGI; John Lawrence and Andree Wylie of Lang Michener Lawrence & Shaw; Dr. Elmer Hara of the University of Regina; and Dr. Fred Casadei.

OVERVIEW

This volume, Volume B: Economic Analysis, addresses the economic feasibility of a Canadian national high speed communications network for research, development, and education (referred to as the Network). It is divided into 7 chapters.

Chapter one defines the problem. The ISTC proposal is shown to be more than a choice between two levels of network speed. The concept of the "technology curve" is introduced to compare the ISTC proposal, which maintains the network at state–of–the–art speeds, with the alternative, a lower speed strategy which upgrades network speeds only when the price of the technology drops sufficiently. Three key questions are examined:

- Are the benefits of the Network greater than the costs?
- Are the additional benefits of the Network over a lower–speed alternative greater than the additional costs?
- Is there a rationale for government sponsorship?

Chapter two identifies the present and future benefits of a high speed network. Two types of benefits are identified: improved productivity of Research and Development (R&D) efforts, and the provision of a test–bed for new products and services offered by the Canadian Information Technology (IT) industry.

The case is made that high speed networks are related to services in the same way that transportation is related to goods. The ability to communicate in multiple forms will permit greater cooperation and specialization among R&D workers. The productivity impact is comparable to the historical impact of transportation on manufacturing industries. Potential applications to be offered by the network are identified, explained, and grouped into categories for evaluation by the benefit/cost model. These classes of applications are,

1. Time–slipped Communications (E–mail & Bulletin Boards)
2. Virtual Terminals (Shared Facilities, Supercomputers)
3. Large File Transfers
4. Real–time Communications (Video Conferencing)
5. Data–Bases
6. Other Applications

Some applications will be available immediately, others at a later time. All are expected to mature over time in their sophistication and use.

Chapter two also provides the definitions of Research & Development, R&D workers, and Information Technology that were employed in the benefit/cost estimation.

Chapter three identifies potential rationales for government sponsorship. They include

- Early Adoption of Productivity Enhancing Technology.
- Overcoming pricing constraints.
- Promotion of Research & Development.
- Overcoming training cost barriers.
- Overcoming network externalities.

- Market Making.
- Industrial Benefits to the IT industry.

Chapter four explains the methodological approach. Because of the significant uncertainties around key factors, a risk assessment approach is used. HICKLING's Risk Assessment Process (RAP), a technique based on Monte Carlo analysis, is employed to take probability distributions of inputs and generate probability distributions of results. The result is the ability to estimate the expected values of benefits and costs, and the uncertainty surrounding the estimates. For example, the analysis might predict an expected value of X, with a 90% likelihood of at least Y.

Chapter four also provides a guide for reading the graphical figures provided by RAP.

Chapter five provides a detailed description of the principles and assumptions employed in the benefit/cost estimation. Each module of the benefit/cost model is explained. The methods of testing for economic feasibility and the validity of government sponsorship are explained.

Chapter six and seven report the results of the benefit cost estimation. In summary, it was found that:

1. **The benefits of the high speed network proposed by ISTC may be expected to significantly exceed costs.**

   The network will allow Canadian R&D workers to share facilities, to collaborate, to access new services, and to overcome the isolation of the small Canadian R&D community. The impact of the increased cooperation and specialization permitted by the network is comparable, in both size and effect, to the historical impact of transportation investments. The productivity gain at maturity has a 90% probability of exceeding 2.4%, a significant gain on an R&D expenditure of $8.3 billion in 1989. The expected productivity gain is 3.0%.

   In addition, the benefits of providing a test-bed facility for Canada's Information Technology industry is also sufficient, on its own, to warrant the investment. The provision of a test-bed offers significant market opportunities to Canadian industry, resulting in increased sales, at maturity, of from $238 to $551 million annually.

   The project is 90% certain to provide a net gain of at least $1.74 billion in present value terms ($1989), approximately 10 times its cost over the 20 year evaluation period. The expected net benefit is $2.23 billion.

   The real rate of return is 90% certain to exceed 50.2%, and is expected to be 61.1%. The likelihood of failing the Treasury Board's 10% rate of return guideline is negligible.

2. **The additional benefit of choosing the high speed network proposed by ISTC over lower speed options is expected to significantly exceed the additional cost.**

   A lower speed network also has a high rate of return, and is significantly cheaper. However, a lower speed network sacrifices all the benefits of a test-bed for the Canadian Information Technology industry, and it significantly postpones productivity gains for research and development.

An IT test–bed requires state–of–the–art network speed to test new equipment and services. The gain sacrificed by settling for a lower speed network and losing the IT test–bed function, is 90% certain to exceed a present value of $403 million, and is expected to be $694.9 million.

The postponement of productivity gains is also a significant loss to the economy. A lower speed network restricts the applications that can be offered and provides poorer service for those seeking to seriously collaborate or share facilities. While the cost of higher speeds will eventually become affordable, the postponement will slow the adoption of new technologies, prevent the introduction of new services, and lose the potential productivity gains during the intervening time. The productivity gains from early adoption of higher speeds is 90% certain to exceed a present value of $550 million, and is expected to be $810 million.

In total the net additional benefit from choosing the high speed network proposed by ISTC is 90% certain to exceed additional costs by a present value of $1.14 billion, and is expected to exceed costs by $1.49 billion.

The real rate of return on the additional investment is 90% certain to exceed 44.8%, and is expected to be 53.2%. The likelihood of failing the Treasury Board guideline rate of return of 10% is negligible.

3. **There is a good rationale for government sponsorship.**

The alternative to government sponsorship is private sector provision. The early introduction of a high speed network is not feasible on a private sector basis. The break–even year (revenues meeting operating costs) is 90% certain to exceed year 9 of operation, and is expected to be year 10. Because of the length of time until break–even, and because the first market entrant is disadvantaged by the costs of market–making, private sector firms are very unlikely to offer a high–speed network.

In addition, sponsorship of the network furthers public goals. Network sponsorship:

- Promotes and supports R&D without having to screen projects.
- Demonstrates the productivity impact of new technologies, encouraging rapid adoption.
- Compensates for market imperfections, including the joint benefits of wide participation in a network and the overestimation of training costs.
- Creates a market–place for the competitive provision and development of information–related services.

The above considerations are a rationale for government sponsorship because they promote industrial productivity and development, and because their benefits cannot be captured by a private sector network provider.

The main text is followed by three appendices. Appendix A provides an alphabetical key to variables. Appendix B provides a module–by–module mathematical description of the model. Appendix C identifies the probability ranges and central values used for input variables, and provides explanations for their choice.

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1. PROBLEM STATEMENT

1.1 A CANADIAN HIGH SPEED RESEARCH NETWORK

Industry Science & Technology Canada (ISTC) is considering assisting in the establishment of a national high speed communications network for research, development and education (R&D). The network would link personnel, equipment and information across the country and around the world.

A number of regional and local networks already exist. The ISTC proposal is to provide a national backbone network which will connect local networks and offer high speed transmission of data among them. Individuals and institutions would also be able to connect to the back-bone network directly.

Two types of benefits are expected from this project; the significant enhancement of productivity by R&D workers, and the creation of industrial opportunities for the Canadian Information Technology (IT) industry.

The network will increase the productivity of R&D workers by:

- Enabling R&D workers to use specialized research facilities, such as super-computers, from remote locations.
- Permitting greater and more efficient collaboration between R&D workers.
- Providing access to, and stimulating the creation of, a variety of services valuable to the R&D community.

Industrial opportunities will be created for the Canadian IT industry by

- Providing a test-bed for network equipment.
- Providing an environment for developing and test-marketing software and services designed to support R&D.
- Providing an opportunity to familiarize a broad user-base with Canadian IT products and establishing user confidence in these products.

The expected benefits are identified and discussed in Chapter 2.

1.2 THE SIGNIFICANCE OF "HIGH SPEED"

The ISTC proposal is not the only form that a national back-bone network could take. For example, a less expensive network offering lower speed is currently being considered with funding assistance from the National Research Council (NRC). It is called CAnet.

The ISTC network would expand on the CAnet concept, enhancing its capabilities and enlarging its scope. The fundamental question is:

"Do the additional benefits of a higher speed network exceed the additional

costs?"

Network speed refers to the amount of data that may be transferred in a given time. For example, the proposed ISTC network theoretically will transfer data 27 times faster than the proposed initial speed for CAnet. Lower network speeds set limits on the types of applications that can be practically used on a network.

For example, the simulation of an atomic process, or the graphic display and rotation of a gene structure, requires continuous transmission of large streams of data. High network speeds are necessary to accommodate these kinds of applications.

In ascending order, the current standard speeds are **56k**bps, **T1** (1.5 Mbps), and **T3** (45 Mbps). CAnet is currently planned for 56k. The ISTC network would start with a speed of T1. The speeds of national networks in other countries are moving quickly to T3. T3 technology is available now, but expensive.

Choosing an appropriate level of technology is a difficult question. More advanced technology is always available at a price. At what point are the benefits of a higher level of performance not worth the additional cost?

1.3 DEVELOPING A REFERENCE CASE

To be economically feasible, a national high speed network must pass two hurdles:

- Its total benefits must exceed its total costs.
- Its incremental benefits with respect to a lower speed national network must exceed the incremental costs.

To answer the latter question, this volume compares the ISTC network to a hypothetical lower speed network requiring a lower level of funding. Because CAnet is the most capable alternative to the ISTC proposal, it is used as the basis for this "reference case".

It should also be noted that the relative evaluation of the reference case is based on this study team's own assessment of the benefits of a hypothetical 56k network such as CAnet, and does not necessarily reflect the opinions, plans, or intentions of CAnet sponsors.

1.4 ADDITIONAL BENEFITS FROM HIGHER SPEED

The additional benefits from the higher speed are expected to be:

- **Industrial Benefits**

  Higher network speed is necessary to obtain the industrial benefits. Network speeds are constantly advancing, and new equipment must be designed and tested to meet the new speed requirements of the market. To provide an adequate test-bed for new equipment, the national network must be operating at the these higher speeds.

  IT service providers require a high-speed network for the same reasons. New software and services must be designed to take advantage of newly available network speeds.

- **Higher Productivity Impacts**

  As discussed above, low network speeds limit the types of applications that are possible and limit the ability of researchers to collaborate with remote colleagues on projects involving large data sets. Chapter 2 describes these applications.

  High network speeds open network use to a wider range of applications and permits greater cooperation and collaboration between Canadian R&D participants.

- **Public Sector/Private Sector Synergy**

  The ISTC network is expected to be more proactive in its encouragement of private sector R&D involvement than the reference case because of ISTC's mandate to encourage increased productivity and competitiveness in Canadian industry. The increased involvement of the private sector is expected to lead to additional productivity gains by permitting greater collaboration between the public sector and private sector R&D workers.

  Chapter 3 details how government sponsorship of early adoption of new technologies can enhance Canadian productivity.

1.5 CHOOSING A POSITION ON THE TECHNOLOGY CURVE

Measuring the benefits of a national high speed network requires more than the comparison between the benefits of 56k and T1 network speeds. As with most advancing technologies, the cost of equipment for a given network speed will drop over time. T1 technology will eventually become affordable at the lower funding level represented by the reference case. The question is one of timing.

When is the best time to invest in new Technology?

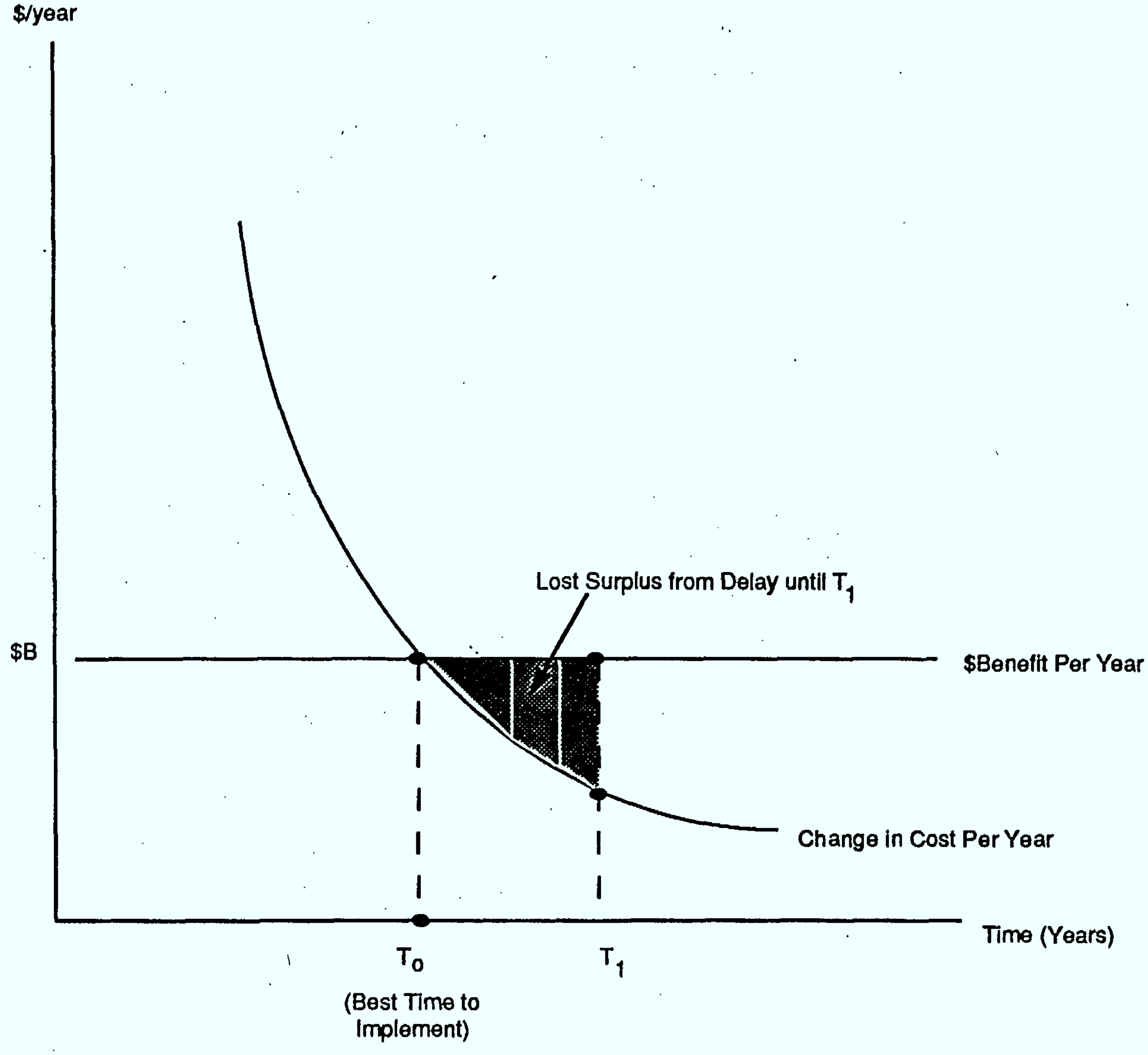
When is the best time to invest in new technology? Even if adoption of a new technology is paying proposition now, it may be more worthwhile to purchase older technology now and wait for costs of more advanced technology to fall. Anyone who has purchased a microcomputer has faced this question.

Figure 1.1 illustrates the problem of when to adopt new technology when its costs are falling. For simplicity, the benefits of adopting the more advanced technology are assumed to be constant at $B per year. Before T_0 the drop in cost each year is greater than the benefits from implementation, so that waiting is worthwhile. Beyond T_0, the price is still dropping, but the lost benefits per year $B are greater than the costs saved by waiting. Time T_0 is the optimal time to adopt the new technology. The net loss per year of waiting at T_1 is illustrated by the shaded area. The total loss of waiting until T_1 would be the area above the change in cost curve and below $B, between T_0 and T_1.

While Figure 1.1 illustrates a useful concept, it is only applicable to a one–time decision. The question facing this study is not just a one–time choice between 56k and T1. As mentioned above, to gain the benefits from increased IT industrial opportunities, the network must constantly operate at the most recently feasible levels of network speeds.

Figure 1.1

INVESTING IN NEW TECHNOLOGY:
THE SINGLE INVESTMENT DECISION



Optimal time for new investment is when
the benefit available that year
equals the cost saving from waiting one year.

To preserve IT benefits, the high speed network must constantly operate at speeds that are higher and more expensive than might be chosen under the more restrictive mandate of the reference case. The reference case is for 56k and the ISTC network is for T1. When prices of technology fall so that T1 becomes affordable at the budgetary level planned for the reference case, a high speed network acting as a test–bed for IT benefits might require T3 speeds. The ISTC network involves consistently higher cost and speed over time.

The Technology Curve

Figures 1.2a and 1.2b illustrate the choice between the ISTC advanced network supporting test–bed functions, and the more restricted approach represented by the reference case. The top figure shows two "technology curves". The technology curve represents the relationship between network speed and cost at any given time. Higher network speeds cost more money. The left hand curve represents the cost/speed relationship at an initial time T_0. As time passes, the cost of providing any given network speed falls. As the cost of each technology falls, the technology curve as a whole falls, appearing in the diagram as the right hand curve T_1. The diagram illustrates the drop in the cost of T1 network speed. The drop in the curve makes it appear to move to the right.

In the bottom diagram (1.2b) we see the problem of choosing a position on the curve. The low speed strategy, represented by the reference case, is to constantly choose a less costly level of service. Initially that is 56k. Later, when costs have fallen and the technology curve has moved to the right, the lower speed network is upgraded to T1. Thus the relative position on the technology curve is maintained at a constant level.

The higher speed network choice is also illustrated on Figure 1.2b. At T_0, when the reference case chooses 56k, the high speed network chooses T1. When T1 prices fall, so do T3 prices. When the reference case upgrades to T1, the ISTC network may be upgrade to T3. Again, for the given level of expenditure the position on the technology curve is maintained. Whether the higher level of expenditure is justified is the subject of this volume on economic feasibility.

1.6 TESTING THE ROLE FOR GOVERNMENT

If the benefits of a high speed network are shown to be greater than the costs, there is still the question of whether government sponsorship is necessary or desirable. Under normal circumstances, if a project survives a benefit/cost test, it is a paying proposition which can and will be undertaken by a profit seeking private sector.

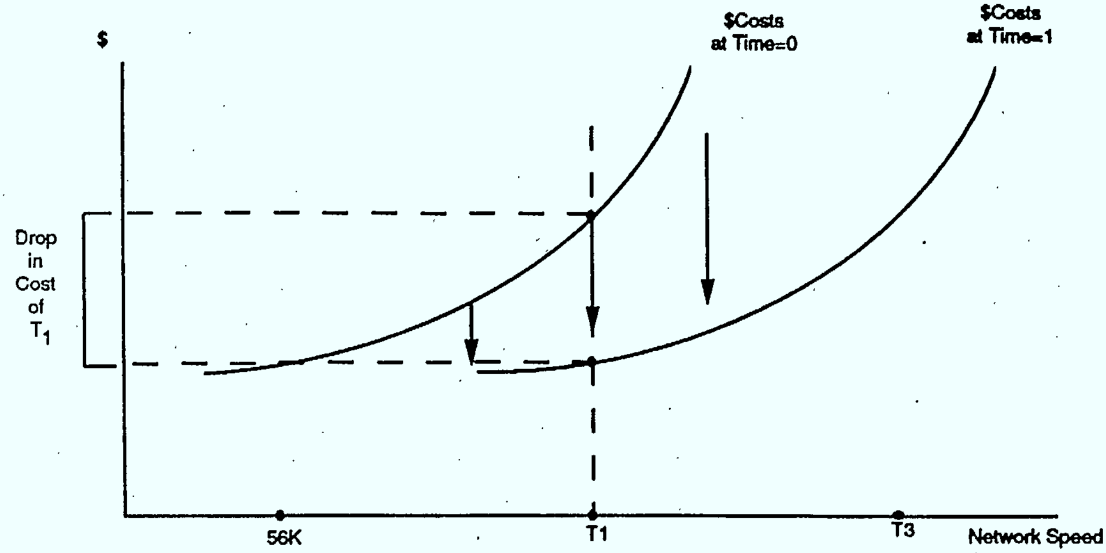
A role for government emerges only when their are significant benefits to society which a private sector enterprise cannot capture. This will occur when markets or information available to entrepreneurs and users have significant imperfections. For example, governments provide most roads because of the difficulty private sector entrepreneurs have of collecting revenues from users. Toll–booth highways are a potential exception.

Therefore, an economic feasibility study of public investment must address the question of whether there are significant public benefits which cannot be captured by a private sector operator.

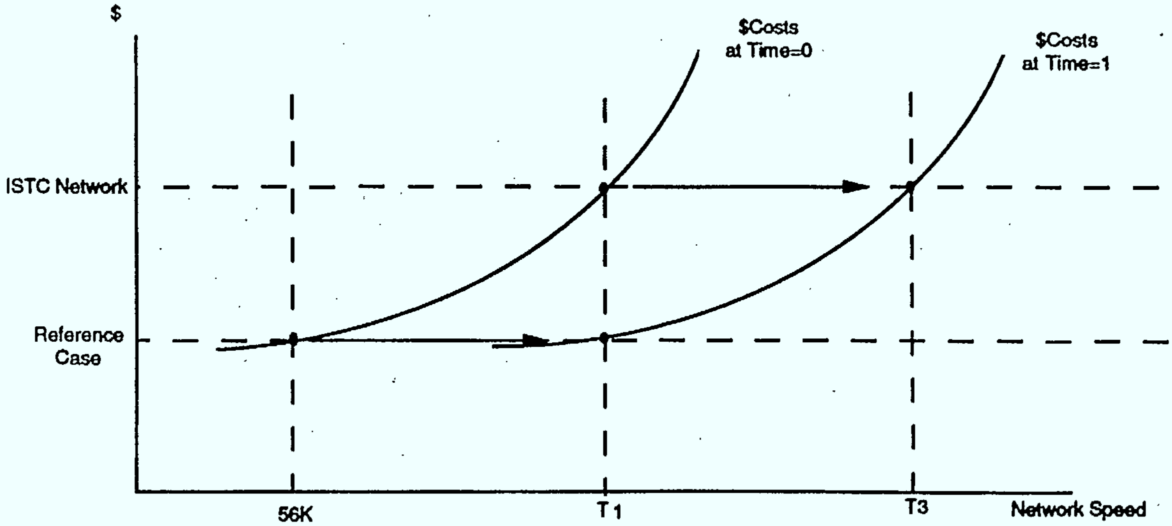
Figure 1.2

CHOOSING A POSITION ON THE TECHNOLOGY CURVE

1.2a: Costs of all Technologies Drop over Time



1.2b: Choosing a Position



1.7 RESTATING THE QUESTION

It is clear that the choice to be evaluated is not a decision between initial network speeds of 56k and T1, but between two strategies for long run levels of expenditure and network evolution. The ISTC network is a strategy characterized by using the newest feasible speeds and products required for developing further IT products (as well as providing greater support for R&D workers). The lower speed network represented by the reference case is a strategy to provide relatively inexpensive service for more restricted applications.

We may restate the hurdles for the ISTC network as:

- **Are the benefits of maintaining a higher speed network greater than the costs?**
- **Are the incremental benefits of maintaining high speeds greater than the incremental costs relative to the lower speed alternative?**
- **Are their significant public benefits which cannot be captured as revenue by a private sector operator?**

These are the questions to be addressed by this economic analysis.

1.8 THE BENEFIT/COST APPROACH

1.8.1 What is a Benefit/Cost study?

The economic feasibility of a public investment is normally assessed using benefit/cost analysis. Benefit/cost analysis is the chosen approach for this study.

In its simplest definition, benefit/cost analysis identifies the individual benefits and costs, places values on them, and adds them up. If the dollar value of benefits exceeds costs, the project is considered worthwhile. Benefit cost analysis is conducted according to standard rules regarding the valuation of benefits and costs over time and the treatment of common issues that arise.[1]

The methodology used in this volume is consistent with the Government of Canada's Benefit–Cost Analysis Guide, published by the planning branch of Treasury Board.

1.8.2 Challenges for This Study

While costs for alternative network speeds are relatively well known, quantifying a dollar value on the benefits from a high speed network represented a serious challenge for this study. HICKLING's review of high speed networks in other countries revealed that no other country has attempted to do so. Those networks which have been implemented in the United States, Japan, and Europe, have gone ahead on a strategic basis without a quantitative assessment of benefits and costs.

With the experience of other countries available, and with the unique expertise in dealing with uncertain data available through HICKLING's RAP process, Canada is in a unique

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1 A reference on the practice of benefit/cost analysis is Mishan, E.J. Benefit Cost Analysis. Praeger, New York.

position to be able to estimate and judge the worth of public investment in a high speed research, development and education network.

To quantify benefits, some difficult questions must be answered. For example:

- How do we measure the worth of R&D, given the wide variety of projects undertaken in Canada and the intangibility of much of the results?
- How do we measure the impact on R&D productivity from communication networks, given that they are only a vehicle for the wide variety of potential applications that must pass over them?
- How do we measure the industrial benefits from creating test–bed facilities for a myriad of potential IT products, many of which are as yet unknown?

The approaches taken to construct a reasonable answer to these questions are outlined in subsequent chapters.

2. IDENTIFICATION OF NETWORK BENEFITS

This chapter:

- Establishes the significance of data communication networks to Canadian economic development.
- Identifies the R&D productivity benefits of a high speed network and explains how they are grouped for the purposes of evaluating them.
- Identifies the industrial benefits of a high speed network.
- Provides the definitions for key concepts such as R&D expenditure, R&D workers, and information technology (IT) industries.

2.1 DATA COMMUNICATIONS NETWORKS: THE TRANSPORTATION COMPARISON

Data communications networks and transportation networks (roads, rail, etc.) are very similar. As networks, they both move things. Physical goods and people are moved by a transportation network. Data and, more importantly, services, are moved by a data–communications network. A business may have its machines delivered by truck, and its money delivered by wire.

The significance of a high speed network for Canadian economic development can be explained through a comparison with the historical role of transportation.

Transportation is well known for its key strategic role in economic development. Transportation shortens the economic distance between people. Although physical distance does not change, cheaper and more efficient transportation makes the transport of goods between two points cheaper, and therefore closer in the economic sense.

By shortening the economic distance, cooperation and specialization become easier. Firms with complementary skills can contract to purchase from one another instead of each providing for themselves. This permits specialization, which in turn increases productivity. Specialized firms are more able to understand and deal with their part of production.

Therefore, investment in improved transportation has historically had two effects on economic development:

- It has permitted specialized firms and institutions to cooperate profitably by shortening the economic distance between them.

- It has permitted greater specialization by firms and institutions, leading to increases in productivity of each firm.

For example, currently automobile parts are made in specialty plants and shipped to assembly plants. There are gains from this specialization because one automobile tire plant may serve a number of different types of auto plants in different locations. If transportation was too expensive, the gains from this specialization would not be possible. Parts production would have to be centralized at each plant. This would mean either wasteful duplication of facilities, or centralization of the entire auto industry in one location. The latter proposition would involve substantial diseconomies of its own.

The impact of transportation investment on development has been especially important for Canada. As a very geographically dispersed country, lowering transportation costs and shortening the economic distance between people and firms is especially important. Historically, transportation policy has been a corner stone of Canadian economic policy and nation building.

2.1.1 The Role of Data Communications Networks in Shortening Economic Distance

Our transportation networks are still growing, but their relationship to the economy is mature. Looking to the future, we may ask how else we may enhance Canadian productivity.

One proposed answer is data communications networks. Where the transportation networks transport goods, data communications networks transmit services and information. For example, instead of maintaining a materials specifications library of its own, a manufacturing firm can access a specifications library service electronically. Instead of processing one's own data, one can send it out. A large variety of industrial services can be provided electronically. As with transportation, this has two effects:

- It permits specialized firms and institutions to cooperate profitably by shortening the economic distance between them.
- It permits greater specialization by firms and institutions, leading to increases in productivity of each firm. New areas of specialization have already emerged. A current example is the developing industry in data–base services. Research which would normally have been undertaken in–house over many days may now be conducted more rapidly electronically. Data–base services act as agents for data–bases, they offer customers access to a wide collection of data–bases from separate sources through a common menu. Documents may also be ordered through the network. Canadian firms such as Infomart and Infoglobe compete with established U.S. firms such as Dialog in this market.

The enumeration of examples of productivity gains available through data communications networks in general is beyond the scope of this study. However, it is within this framework that we may place and elaborate on the specific benefits of a high speed R&D network to the Canadian R&D community.

2.1.2 Benefits to the R&D Community

R&D is an information intensive activity. It is in support of R&D that the productivity gains from data communications networks are most likely to be significant. In broad terms, we may characterize the productivity gains in two ways:

- **Gains from Cooperation:**

  R&D workers become highly specialized in their respective fields. However, progress in science and application in industry requires cooperation and information sharing among specializations.

  Barriers to cooperation are significant. The appropriate experts for a project will often be in separate locations. The first barrier to cooperation is simply being aware of the benefits they can offer each other. Currently, awareness is based on encounter through journals, publications, and conferences.

Once the benefits of cooperation are known, physical barriers to cooperation arise. Written communication is delayed by fax distribution; multi-page documents must be copied and couriered, and large data sets must be put onto to tape and removed from tape at the other end. The cumulative toll of detail renders much collaboration infeasible in the absence of networks.

A high speed network allows screen-to-screen communication of information. By lowering the costs of collaboration, more cooperation between researchers become possible, with a consequent increase in productivity.

- **Gains from Specialization**

  A high speed network permits increased specialization in a number of ways.

  - Shared facilities: Facilities such as super computers may be provided in one location, but used by remote locations.

  - Access to new services: Specialized software can be provided and maintained at central host machines. R&D researchers in other locations who find a use for such tools can login to the host machines and use them remotely.

  - Greater R&D specialization: The ability to collaborate easily will allow R&D firms and institutions to specialize more fully in their respective areas, with the confidence that collaboration with other firms and locations is feasible.

2.1.3 Significance for Canada

These gains are particularly significant for Canada. It has often been noted that Canadian R&D is a low percentage of Canada's total production (GDP), and that most private sector R&D is done by a small group of large firms. The absence of a strong R&D community has been argued to have negative effects on the ability of Canadian industry to innovate, and to spawn new opportunities.

A high speed R&D network, by shortening the economic distance between R&D workers, can give Canadian R&D access to the North American and world R&D communities.

As network communication tools become more varied and effective, a high speed network makes location less relevant to where R&D is undertaken. Firms in Canada will find it more feasible to undertake R&D in Canada because they will be less isolated from the other R&D communities around the world.

Similarly, the location of R&D within Canada will become less relevant. This offers significant benefits to regions of Canada which have not historically had a strong R&D presence, but which hope to enhance local economies by promoting development of "high-tech" industries.

2.2 PRODUCTIVITY IMPACTS OF SPECIFIC NETWORK APPLICATIONS

An "application" may be defined as a given capability or service offered by the network in support of R&D. Potential applications for a high speed network are numerous and varied. Many are available in a mature and effective form now. Others require development of network speed and capability.

To assist the identification and quantification of benefits, applications have been divided into five generic groups:

1. **Time-slipped Communications**

   Information (text, audio, or visual) is sent to a recipient who examines it a some future time. A common letter is a traditional example of time-slipped communications. Two examples of network applications are electronic mail and bulletin boards. These forms of communication are inexpensive, have a short turn-around time, and provide easy access to a large number of people.

2. **Virtual Terminals**

   A person can access a remote facility in the same manner as a person at the facility, obtaining similar capabilities and response times. Facilities include expensive and scarce research apparatus such as super computers, radio telescopes, and medical imaging equipment.

3. **Large File Transfers**

   Research collaboration, especially in the sciences, often requires the exchange of large volumes of data. Files such as medical and satellite images are particularly data intensive. Changing images from visual models place very heavy demands on network speeds.

4. **Real-time Communications**

   Interaction with one or many people which occurs without delay. normal conversation between two people is a traditional example. Network applications range from sharing typed messages, through sharing graphics on computer screens, voice communication, and video conferencing which allows full visual and oral interaction.

5. **Databases**

   One of the most important keys to successful R&D is knowing what information is available and how to access it. Electronic databases and digital libraries speed the identification and recall of information.

The above applications have been included and accounted for in the benefit/cost analysis contained in this volume. In addition, there are other beneficial applications which were not included because of the difficulties in anticipating the form of their application and the degree of their benefits. They include the following:

Distributed Processing – Computer work is distributed among two or more remote processors, from one terminal and operator.

Distance Education – One or more students and a remote instructor are linked electronically. The instructor could be a computer program.

Group decision support systems – The formulation and solution of problems by a group of people is facilitated by computer supported communications and decision making technologies.

Additional descriptions of applications may be found in Volume A.

Some of these applications, such as electronic mail and bulletin boards, are well developed and will have immediate productivity impacts. Others will have limited productivity impacts now, but may be expected to develop in the future. All application groups are expected to have increasing productivity impacts over time.

2.3 INDUSTRIAL BENEFITS

A key feature of the ISTC proposal for a high-speed network are the benefits for Canada's Information Technology (IT) industries. Industrial opportunities will be created by:

- **Providing a test-bed for equipment used to support the network.**

  Canada has a strong telecommunications industry which competes in the world market. A key market for in both the present and the future is the manufacture of routers and other network supporting equipment. In the current environment there is a growing market for equipment serving T1 levels of network speed. Canadian manufacturers are moving to meet this demand and would benefit from a test-bed.

- **Providing an environment for developing and test-marketing services designed to support R&D.**

  Two kinds of services are envisioned. The first are services to facilitate network operations. The second are application services which provide the intelligence to the network for the end-user.

- **Providing an opportunity to familiarize a broad user-base with Canadian IT products and establish user confidence with these products.**

  User familiarity and confidence with equipment, software, and services on the network is expected to lead to greater sales of Canadian products. The ISTC network provides for using Canadian sources as suppliers of first choice for the network.

As discussed under "choosing a position on the technology curve" in Chapter 1, the role of the network as an equipment test-bed requires that it operate at the highest practical speeds. Network speeds are constantly advancing, and new products must be designed and tested to meet the new speed requirements of the market. IT service providers can benefit from a high-speed network for the same reasons. New services must be designed to take advantage of newly available network speeds.

2.4 DEFINITIONS USED IN THE REPORT

The intention of the ISTC network is that it would be accessible to the broadest meaning of research, development, and education activities. This includes all of the elements of technological innovation, as well as research, development, and education in non-technical fields of the social sciences and humanities.

It was felt, however, that quantification of the benefits to the non-technical and education applications of the network could not be done to the same level of certainty as the technical applications. For the purposes of this economic analysis only the technical research and development applications have been considered. The results, therefore, underestimate the true value of the network.

2.4.1 Research and Development (R&D)

Technological innovation consists of three main elements: research and development which results in new ideas; education and information services to develop the personnel to support the ideas and design; and engineering and marketing to implement, disseminate and integrate the ideas.

Canada uses the definition of R&D found in the *Frascati Manual* published by the Organization for Economic Cooperation and Development (OECD). It is "... creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications."[2] Canadian statistics on R&D reflect the resources committed to domestically performed work. It is focused primarily on industrial research carried out in the private and public sectors and in institutions.

Distinguishing R&D from a wide range of other related activities is difficult because these activities can be closely linked through information flows or in terms of personnel, operations and institutions. A good example of this is the university sector where the R&D and education functions of an individual frequently overlap. An awareness of these areas of definitional uncertainty helps in understanding some of the constraints to the definition of R&D activity. These areas include:

- Education and training
- Other areas of science and technology (S&T) activities like quality control which may be the subject of R&D at certain times
- Other industrial activities

This last item is possibly the greatest source of error in measuring R&D expenditures. The problem here is defining the cut-off point between R&D and the implementation and realization of an innovation. Design engineering and manufacturing start require some R&D themselves but are considered the next step beyond R&D at the same time.

These definitional problems have not been solved by any one organization which compiles data on R&D. However, it is important to be aware of them and to understand that variances in R&D are bound to occur.

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[2]OECD, The Measurement of Scientific and Technical Activities – Proposed Standard Practice for Surveys of Research and Experimental Development, (Paris: OECD, 1981), p. 26.

2.4.2 R&D Expenditures

This is the principle means of measuring R&D resources; the other being R&D personnel. The chief disadvantage of measuring R&D in monetary terms is that it is vulnerable to differences in price levels and currency values over time. However, data on financial expenditures is generally more precise than measurements of personnel which must be calculated on a person year basis and are weakened by the fact that many non–R&D personnel spend portions of their time on R&D.

There are two types of R&D expenditures: intramural and extramural. Intramural expenditures are defined as all expenditures for R&D performed within a statistical unit, regardless of the source of funds. This includes both capital and current expenditures. Extramural expenditures are funds expended by one statistical unit for R&D performed by another.

For this report we have chosen to use intramural expenditures as we wish to focus on the expenditures of the *performers* of R&D.

2.4.3 R&D Personnel

Personnel is considered supplementary to the basic measure, intramural expenditure on R&D. However, personnel is important since 50 to 70 percent of all R&D expenditures are labour costs. It is a reasonable short–term indicator of R&D level of effort and is important for policy planning in measuring future needs.

Personnel are classified both by occupation and by formal qualifications. The former is broken down into researchers, technicians & equivalent staff, and other supporting staff. The latter system uses categories including: university graduates, holders of other post–secondary diplomas, and high school graduates. Statistics Canada uses the occupational method of classification.

Researchers are identified "as scientists or engineers engaged in the conception or creation of new knowledge, products, processes, methods and systems." This level also includes managers and administrators of R&D projects as well as post–graduate students. Technicians and equivalent staff "participate in R&D projects by performing tasks normally under the supervision of scientists and engineers or researchers in the social sciences and humanities." Other supporting staff include "skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects or directly associated with such projects."

Since there are many in the R&D field who are not 100% dedicated to R&D it is necessary to express their numbers on a full–time equivalent (FTE) basis. If only those persons employed in R&D institutions were counted the result would be an underestimate. Likewise, if all those performing R&D work were counted the result would be an overestimate

2.4.4 Categorization of R&D Performers

There are five sectors of R&D performers as defined by the OECD. These are:

- Business Enterprise
- Private Non–profit Organizations (PNOs)
- Government
- Higher Education
- Abroad

For the purposes of this study we have reduced this list to three categories which are:

- Private Sector
- Government
- Institutions (including PNOs and Universities)

The foreign category is beyond the scope of this study. We have grouped higher education and PNOs into one category because the types of R&D and personnel in these sectors are similar and because the PNO sector accounts for less than 1.5 percent of all R&D expenditures in Canada.

There are two principal reasons for categorization of producers. First, since each sector has its own characteristics and its own mix of R&D, the classification allows us to delineate more clearly between the level and direction of R&D on a national scale. Second, the sectoral approach is the most reliable way to build up a national aggregate of R&D production.

2.4.5 IT Producers

Information Technology (IT) consists of eight major components as defined by the CANTECH database[3]: Factory automation equipment, Computer hardware, Medical equipment, Photonic equipment, Services, Computer software, Subassemblies/subsystems and Telecommunications equipment as defined by the CANTECH database. Listed below are the major sub-groups for each component:

Factory automation equipment

- Robotic Arms & Attachments.

Computer hardware

- Computer Hardware
- Computers
- Special Needs Hardware
- Other Computer Hardware
- Business Equipment
- Peripherals
- Accessories/Components

Medical Equipment

- Medical Imaging Systems

Photonic Equipment

- Acousto-optic Equipment
- Displays
- Optoelectronic Devices
- Cameras and Related Equipment
- Fibre Optics & Related Equipment
- Lasers/Laser-related Equipment

Services

- Artificial Intelligence
- Computer Services
- Photonics Design Services
- Holographics Services
- Automation Services
- Photonics Consulting Services
- Fibre Optics Services
- Laser Services

3 The CANTECH database is owned and operated by Hutchison Research.

- Photonics R&D Services
- Telecommunications/Communications

Computer Software

- Artificial Intelligence
- Industry–specific Software
- Systems Software
- Other Software
- Non–industry Specific Software

Subassemblies/Subsystems

- Connectors/Packaging
- Electron Tubes
- Semiconductors/Devices
- Electronic Systems
- Transducers
- Electronic subsystems (exceptions include Thermal Generators and Nuclear Instrument Module Power Supplies)

Telecommunications Equipment

- Transmission Systems/Equipment
- Other Telecommunications
- Satellite/Microwave Equipment
- Telephone/Voice Equipment
- Data Communications Equipment
- Audio/Video Equipment
- Broadcasting/Receiving Equipment

3. POTENTIAL RATIONALES FOR GOVERNMENT SPONSORSHIP

As established in Chapter 1, there are three hurdle questions which the proposed ISTC network should pass to be considered economically feasible:

- **Are the benefits of maintaining a network at high-end speeds greater than the costs?**
- **Are the incremental benefits of maintaining high-end speeds over low-end speeds greater than the incremental costs over lower end speeds?**
- **Are their significant public benefits which cannot be captured as revenue by a private sector operator?**

This chapter addresses the third question. If the benefits of a high speed network exceed the costs then, under normal circumstances, a profit seeking private sector could be expected to provide the network. In order for government sponsorship to be required, there must be factors which limit the ability of a private sector provider to recover the benefits through revenues. If such factors exist, then private provision of a high speed research network would either:

- not be provided,
- provided significantly later than would be best for the Canadian economy, or
- provided at a lower level of service than is desirable.

When firms are unable to fully charge for the benefits they create, it called an "externality" (as in "external to the pricing system"). The following sources of externality may provide reasons for government sponsorship of a high speed research network:

- Benefits from early adoption of technology.
- Inability to price discriminate.
- Under investment in research and development.
- Training costs externality.
- Networks externality.
- Market making.
- Industrial benefits.

This chapter elaborates on the above. Each of these reasons is incorporated into the benefit/cost estimation of Chapters 5 and 6. Chapter 5 sets out a specific tests for whether the quantitative impacts of these concerns are sufficient to motivate government sponsorship. Chapter 6 reports the results, in conjunction with the other benefit/cost assessments.

3.1 GOVERNMENT'S ROLE AND THE TRANSPORTATION COMPARISON

The previous chapter on benefits of the network drew a parallel between the benefits of data communications networks and the benefits of transportation to Canadian economic development. A similar case is often put forward for government's sponsorship role. If data communications networks are the highways of the future, should not the government provide them in the same way as governments have provided the roads?

The case for this argument is not clear cut. Roads are provided by the government because the private sector would not provide the necessary level of road construction by itself. The private sector has no efficient means for collecting revenues from the users of roads. The logic with respect to other transportation modes is similar. Transportation facilities are shared facilities, and out of that stems a myriad of difficulties in recovering revenues from the beneficiaries which lead to reasons for government involvement.

Are such reasons present in the case of a high speed research network? Potential reasons for government sponsorship which meet this criteria are presented in the following sections.

3.2 PROMOTING EARLY ADOPTION OF NEW TECHNOLOGY

Without assistance, the private sector tends not to adopt efficiency enhancing new technology soon enough. As a result, there is a role for government in providing an inexpensive vehicle for the early testing and demonstration of new technologies.

When a firm risks the adoption of a new technology, it considers only whether the expected net returns to itself are positive. However, the benefits the technology adopting firm creates are two fold, the benefits to itself, and the benefits to other firms who will learn from its example. If the new technology is successfully applied, other firms will follow suit in adopting the new technology. They will have gained from the risk undertaken by the first firm.

Since the initial risk taking firm is unable to charge the other firms for the benefit of its example, it will disregard this benefit when deciding whether to adopt new technology. Thus from a social benefit perspective, this means that if firms are left to their own devices new technology is not adopted as often or as quickly as is desirable. There will be times when the risk of adopting a new technology is too much for one firm, but worthwhile for an industry to see one firm make the attempt.

This process of technology adoption is illustrated Figure 3.1. Consider the top diagram. The vertical access is expected dollars cost or benefit. The horizontal axis represents the "distance" from the area of specialization; how far the organization is from understanding and evaluating the benefits of a new technology. The dotted line, representing the true net benefit, is positive. The line E(NB) represents the expected net benefits of adopting a new technology by firms. Firms closer to the area of specialization related to the technology will be closer to seeing the truth, but as long as their expected value is still negative, they will not adopt it. This view is shown by the E(NB) curve rising on the left, but not crossing into the positive range.

As time passes, firms closest to the technology perceive that the benefit may be positive, although they do not know without adopting it. Those firms who expect a positive return go ahead and adopt. The rest delay. This is illustrated in the middle diagram of 3.1.

After some firms adopt, the process of demonstration by example begins. Firms further away from the source of innovation see neighbouring firms successfully adopting the new technology and follow suit. This is the bottom diagram. As each firms adopts the new technology, society experiences the net gain represented by the shaded area.

Once the process of demonstration by example begins, it grows exponentially until it has spread to all relevant firms in the economy. This is illustrated by Figure 3.2.

Figure 3.1

EARLY ADOPTION
OF NEW TECNOLOGY

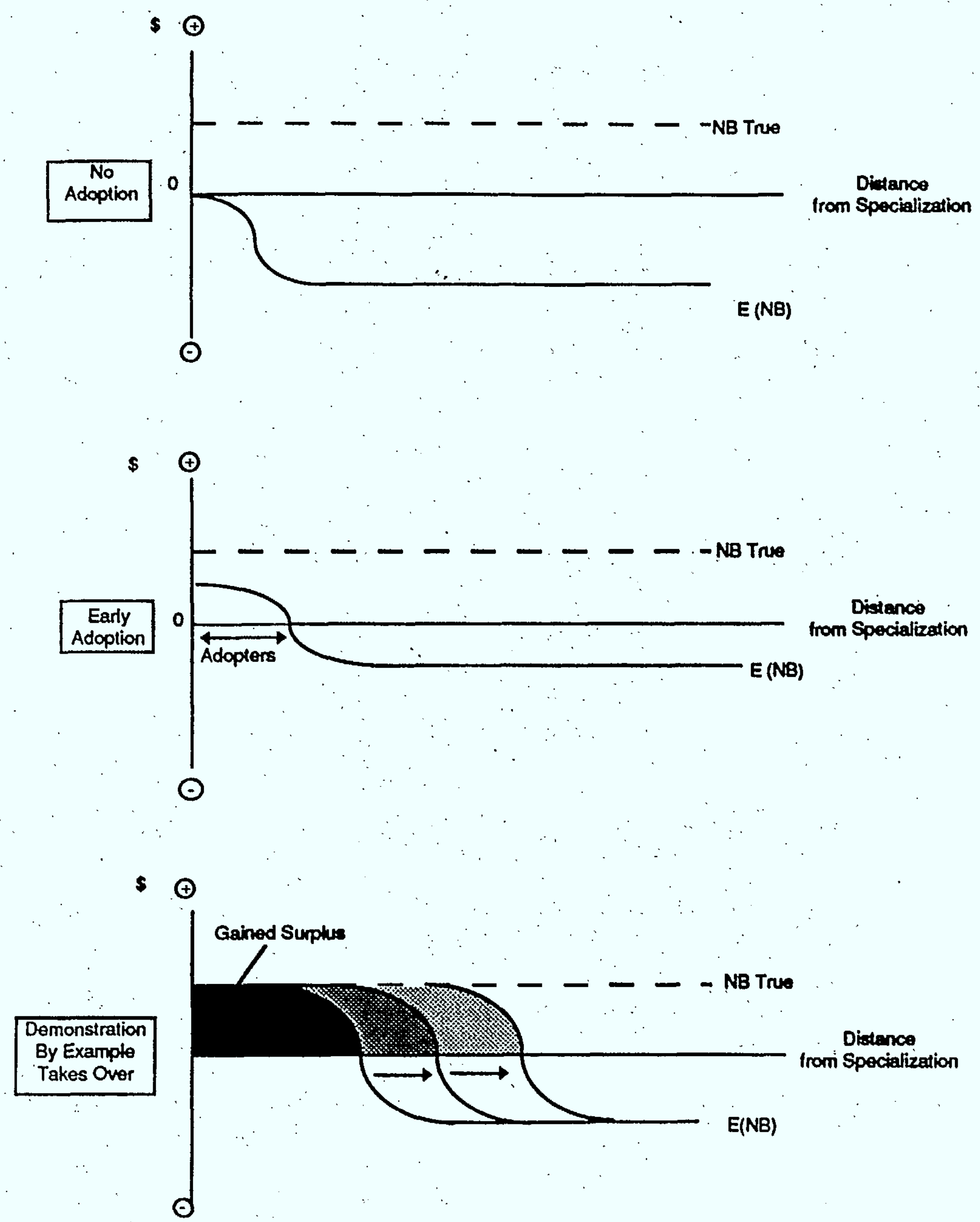
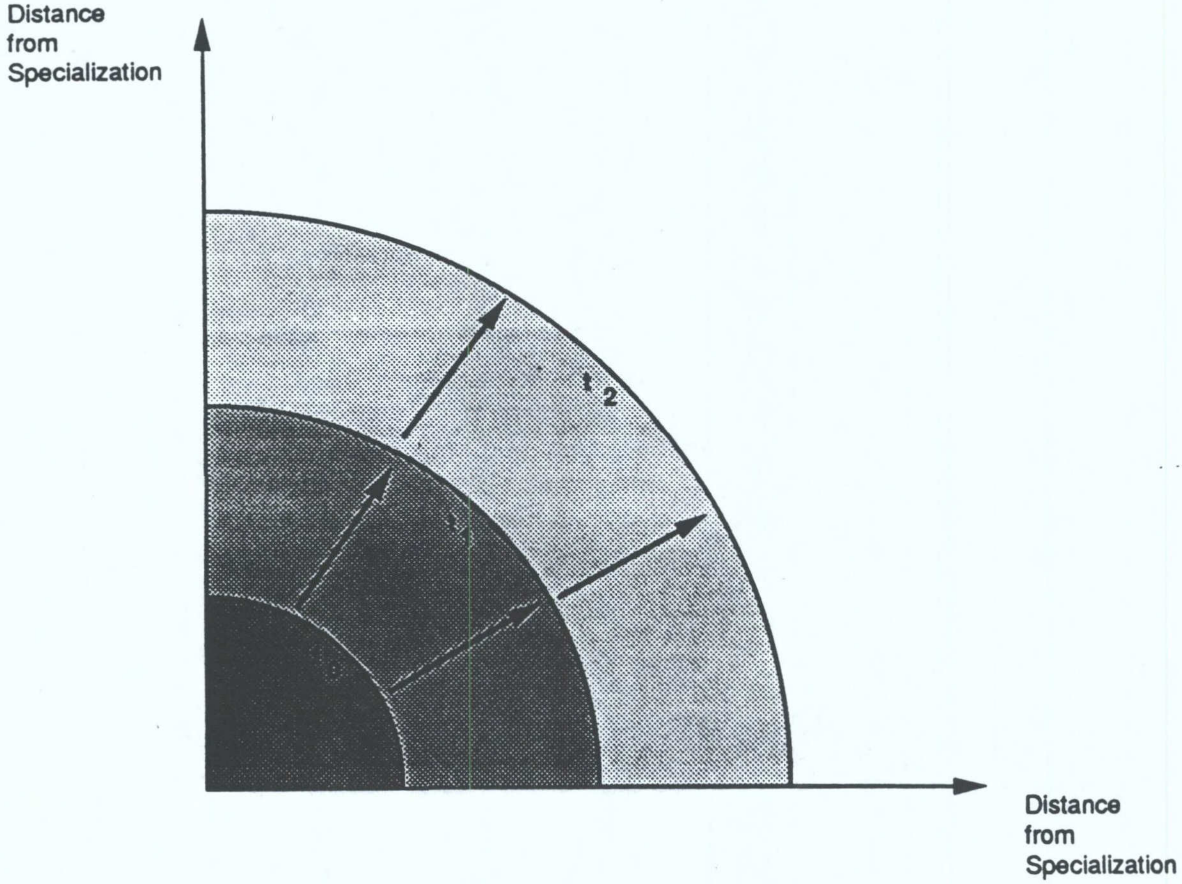


Figure 3.2

Adoption of New Technology is Exponential



The end benefit from testing and demonstrating new technologies can be quite large if they prove successful. Since early adopting firms will consider only their own benefit and not the total benefit to the economy, governments have a role to play in encouraging risk taking in technology adoption by subsidizing or assisting in technology demonstrations.

The high speed network meets the definition of a demonstration of new technology on two fronts. First, use of a high speed network facilities is itself a new technology for many firms. By sponsoring initial efforts to establish the network, attractive rates may be offered to potential subscribers to encourage them to try the new technology. Later, as the productivity gains possible through the networks are realized, firms will be willing to pay the full value of the services.

On the second front, the network's test–bed function has the important side effect of constantly exposing R&D subscribers to new types of software and services at inexpensive or free rates. This familiarizes firms more quickly with emerging technology and accelerates the process of technology adoption for both R&D firms, and other firms which will follow their examples. The net result is an economy that is more responsive in adopting productivity enhancing technologies of this sort.

Therefore, one potential reason for government to sponsor the high speed network is as a demonstration project and as a vehicle for demonstration projects.

3.3 PRICING EXTERNALITY

An "externality" is any feature of a situation which prevents one firm from charging another firm for the benefits it provides them. In the previous example, the inability of a technology adopting firm to charge other firms for the benefit of watching its example was is an externality.

Another externality is found in the inability to "price discriminate". It is common practice in our society to charge everyone the same price for a service. Thus we all pay the same price for the same loaf of bread. Exceptions to this rule are called price discrimination. For example, movie theatres charge one price to children and another to adults for watching the same movie.

Price discrimination is unusual because it can only be carried out under specialized circumstances. You must be able to tell which customers are willing to pay more, and you must be able to prevent customers receiving the lower price from reselling to customers receiving the higher price.

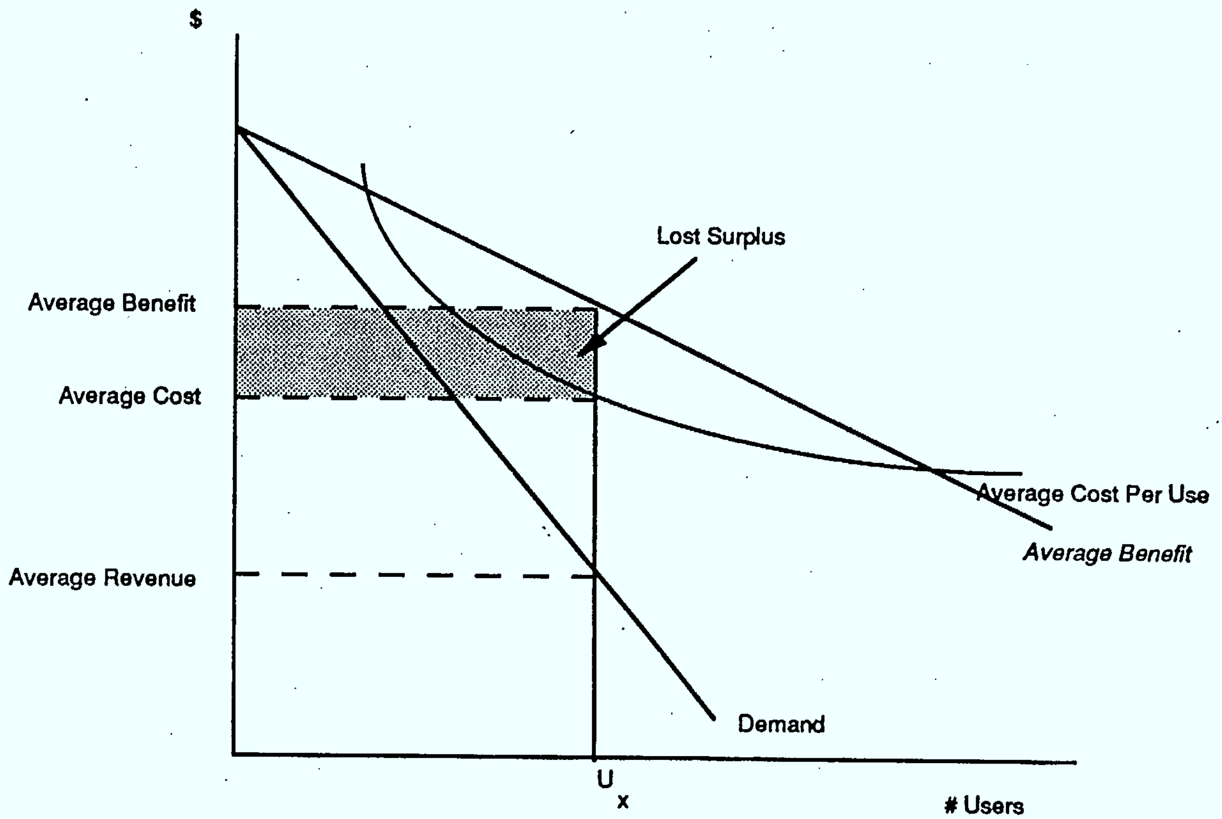
The inability to price discriminate in most markets is not usually considered a problem. However, it can be a problem in the early provision of central services such as networks.

The provision of a network has a large fixed cost base. Average cost per user declines with the number of users. At early stages of a technology like networks, it is possible that there is no single price which attracts enough users to cover the average costs at that price, even though the benefits of a the network exceeds its costs.

This situation is illustrated in Figure 3.3. The demand curve represents the number of users who will subscribe at any given subscription price. The average cost curve lies above the demand curve, indicating that there is no level of user subscribership for which average cost is below the demand price. For example, the diagram shows the average cost above the average revenue (price) when the number of users is equal to U_x.

Figure 3.3

PRICING EXTERNALITY



Inability to capture all user benefits through charges can delay implementation

Figure 3.3. also shows that the network is of positive social benefit at U_z. This follows from the downward sloping demand curve. Because some users value the network more than others, as the price falls the average benefit per user will be less than the price necessary to attract the last user. Thus the average benefit per user always lies above the demand curve. At U_x the average benefit is shown to be above the average cost, and the net gain for providing the network is equal to the shaded area. This area is lost if the network is not provided.

If a private sector network were able to charge each user a different price (price discriminate), it would be able realize an average revenue equal to the average benefit and be able to finance the network. However, this is unlikely.

Therefore, if fixed costs are high relative to the initial volume of demand for a high–speed network, there may be a rationale for government intervention. The private sector may be unable to offer the network profitably even though its total benefits exceed its total costs.

While costs will ultimately fall over time until private sector provision becomes feasible, waiting will postpone adoption of all the productivity enhancements that the network is expected to provide. Because new technology adoption grows exponentially, delaying adoption by the initial user base delays the adoption of productivity enhancements by many more firms in subsequent years.

3.4 EFFICIENT SUPPORT OF RESEARCH & DEVELOPMENT

It is known that there is insufficient investment in R&D in Canada. Because the high speed network is intended to support R&D, one potential reason for government sponsorship of the network is to promote R&D in an efficient manner.

Three reasons are commonly given for believing there is under investment in R&D in Canada. They are:

- Imperfect Intellectual Property Laws
- Imperfect Capital Markets for financing R&D
- The Predominance of Branch Plants in the Canadian Economy.

The first two apply in some degree to all nations, and are often used to justify an ongoing government presence in R&D efforts.

The text below elaborates on each of these problems, and then speaks to the advantages of the high speed research network as a tool in supporting R&D.

3.4.1 Imperfect Intellectual Property Laws

The problem of protecting intellectual property is common to all countries. Copyright and patent laws provide only limited protection for firms developing new technologies. A large portion of the benefits of R&D carried out by one firm benefit other firms in ways that cannot be charged for. The discovery of one technology can lead to the discovery of others. The expiration and imperfection of patents leave windows of opportunity for exploitation by firms who did not perform the original R&D. There are many reasons, both legitimate and illegitimate, why firms are unable to capture the full value of their R&D in their revenues.

The net result is that firms do not carry out as much R&D as is desirable. The inability of private sector firms to capture all of the benefits of their R&D leads to under investment. They will invest in R&D only to the point that returns to themselves are positive. Accounting for additional returns to other parts of the economy would lead to higher investment.

Figure 3.4 illustrates this point. The cost of each additional dollar of R&D (marginal cost) is, naturally enough, one dollar. The private marginal benefit curve represents the profit earned by a firm on each additional dollar of R&D. The downward slope of this curve represents that fact that initial returns to investment in R&D are high, but the returns on additional investments receive diminishing returns. The social marginal benefit curve reflects the additional benefits from R&D to all society. It is higher than the private marginal benefit because it includes the firms profit plus additional benefits accruing to other parts of the economy. It is also downward sloping because of diminishing returns.

A firm will invest in R&D up to the point S_0, where the profit from the last dollar spent just covers the cost. At this point, the returns to society from another dollar invested are still positive, as indicated by the point marked "Actual Marginal Benefit per Dollar". The desirable level of expenditure is S_1 where the return to all parts of the economy has declined to equal cost. The shaded area indicates the dollar value of the benefits lost to the economy from under investment in R&D.

3.4.2 Imperfect Capital Markets for R&D Finance

Financing R&D efforts is complicated by imperfect information on the part of investors or lenders. The investor/lender is unable to assess the likely return of an R&D project to the same degree of accuracy as those who intend to undertake it. This creates what is known as an "agency problem". Investors/lenders will protect themselves by ensuring that the initiators of the R&D project have risked substantial capital of their own on the project. Therefore, the amount of financing available to R&D through capital markets is limited by the equity held by those seeking financing. This places a significant restriction on the financing of R&D.

As a consequence, less R&D is undertaken then would be desirable for the economy.

3.4.3 Branch Plant Structure of the Canadian Economy

Canada spends a lower percentage of its Gross Domestic Product on R&D than other "high–performing" developed nations. For example, in 1987 Canada spent 1.40% of its GDP on R&D, compared with 2.87% by Japan, 2.82% by Sweden, 2.81% by the Federal Republic of Germany, and 2.69% by the United States.[4]

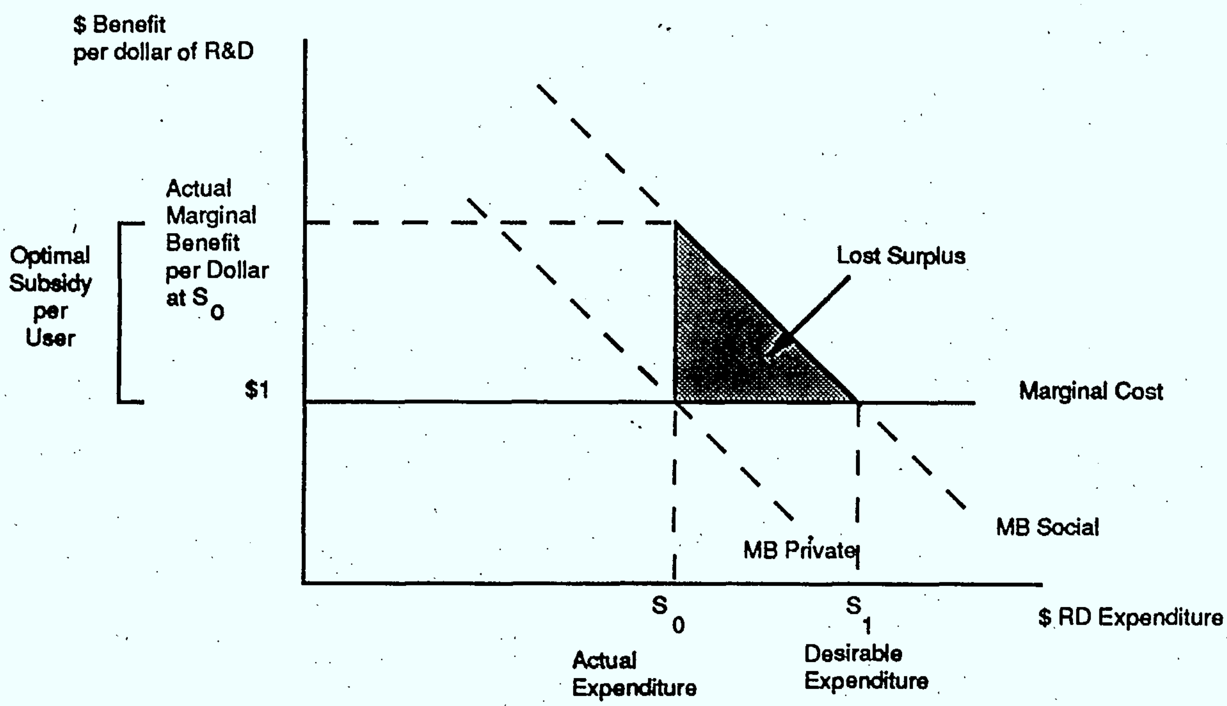
The most common reason offered for the relative difference between Canada and other nations is the predominance of branch–plants in the Canadian economy. Canada has an unusually high degree of foreign ownership in its economy. Much of the productive capacity is represented by branch plants of multi–national companies, who will tend to perform their R&D in their home countries.

It often proposed that the absence of a strong Canadian R&D community inhibits the ability of the Canadian economy to innovate and develop new industries.

[4]OECD estimates.

Figure 3.4

R&D EXTERNALITY



Inability of private sector to capture all R&D benefits leads to underinvestment in R&D

3.4.4 Role of the Network in Efficiently Supporting R&D

If there is under investment in R&D in Canada, then the government can play a constructive role in supporting and stimulating R&D. A variety of tools are at hand, including subsidies and tax credits.

However, direct support of R&D through subsidies and tax credits has strict limits on its effectiveness. The same problem of imperfect information which faces private third party investors also faces governments. Recent difficulties in R&D tax credits underscore this problem.

The research network is an efficient means of promoting R&D for two reasons:

- It's costs are largely fixed. Once established, it provides a better environment for all R&D without requiring additional expense for each new R&D project being assisted.

- It does not require the screening of projects for assistance. Because it is an "in-kind" form of assistance, there is no money to be made from creating "paper" projects. The more viable a project, the more useful it will find the network, and the greater the support the network will have provided.

- It connects Canadian R&D more closely with world R&D communities. The network provides the ability to tie into other countries networks, particularly those established in the United States. If Canadian R&D suffers from lack of synergy due to isolation, the network will help alleviate the problem.

3.5 TRAINING EXTERNALITY

Under an expanding user base, potential network subscribers will tend to overestimate the costs of maintaining staff expertise to use the network. This will lead to a delayed establishment of a network, and a slower growth of the network than is desirable for Canadian productivity growth.

Government sponsorship in the network can advance the date of establishment and accelerate growth in the user base by permitting lower costs to be offered in the initial period.

3.5.1 Overestimating Training Costs

Early adopters of a new technology are handicapped by having to be the first to train staff to use the new technology. There is no possibility of existing staff or new hires being familiar with it. As a technology matures, the labour force becomes familiar with the new technology, and their is a reasonable probability that new hires will not require training.

The initial cost to early adopters of having to train and maintain their staff in a specialized skill can delay the adoption of a new technology such as use of a high speed network. However, if the network is anticipated to eventually achieve broad acceptance in the R&D community, the size of this initial cost may be overestimated by early participants.

The source of the overestimation is the failure to account for the benefits of cooperative action. When each firm trains its own staff, it is also reducing the training costs of other firms. This is because natural turnover in one firm's R&D staff will enrich the trained labour pool available to other firms.

Figure 3.5 illustrates this training externality. The productivity benefits of the network to subscribers generate a demand for network subscription represented by the curve D. The last person to subscribe is the one whose own benefits from the network just meet the cost of subscription. However, each person who joins the network benefits themselves as well as others by enriching the labour pool with trained staff who will later be available to others. The total benefit to the economy of each successive subscriber joining is represented by D_1. At the illustrated subscription price, subscribers number U_0. At U_0 the last subscriber's benefits just equal the subscription price, but the total benefit to the economy of another subscriber is as shown. The gap between the private benefit and the social benefit is the reduction in training costs to other firms provided by the subscribing firm. Assuming that the subscription price represents cost, the desirable number of network users is U_1.

In early stages of network development, the perceived costs of training staff to take advantage of network services may be significant. In this case, the overestimation of training costs will be significant and network establishment and growth can be artificially delayed. The problem may be overcome by either all subscribers up to U_1 contracting jointly to subscribe, or by government sponsorship.

Government sponsorship can achieve the desirable level of initial subscribership by achieving an effective subsidy per user equal to the gap between total economic benefits and private benefits (as illustrated).

The potential impact of early network establishment and early growth should not be underestimated. Recall from Figure 3.2 that adoption of productivity improvements in the economy proceeds exponentially. An earlier beginning in the subscriber base will have a large impact on the subscriber base in later years.

3.6 NETWORK EXTERNALITY

Another reason for government sponsorship of the network is known as "network externalities". When one firm joins the network, it benefits not only itself, but other firms who wish to communicate with it.

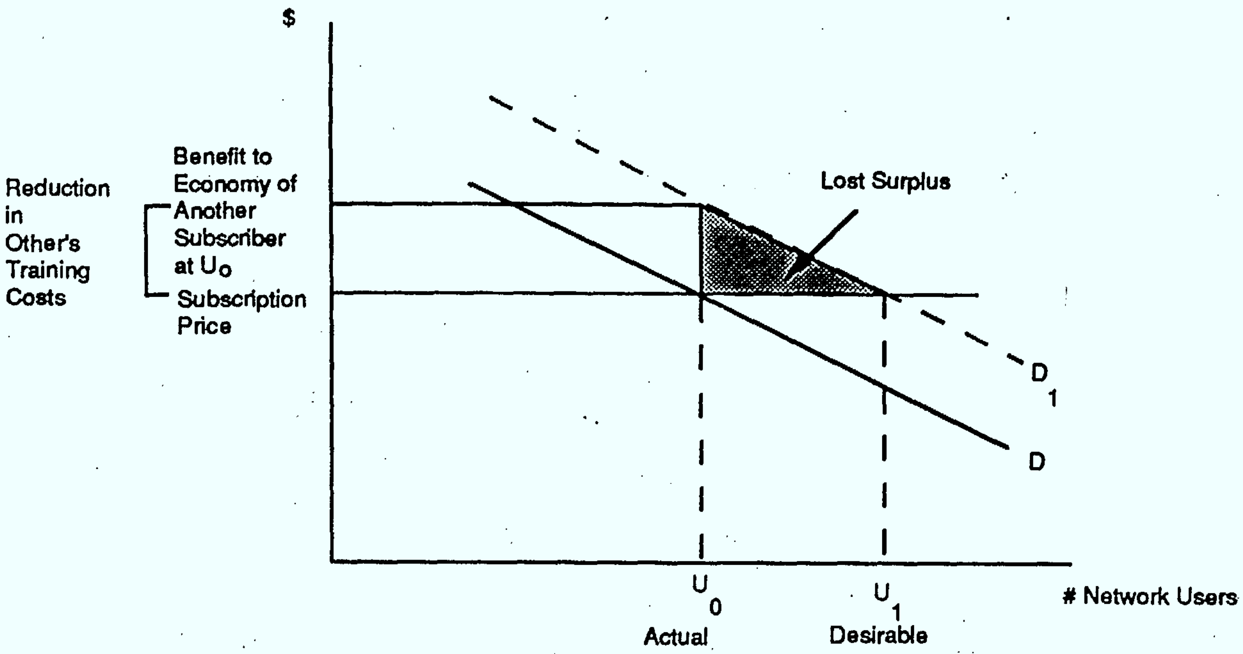
For example, there is no point owning a telephone if no one else does. If the establishment of a network was left up to individual action, they would never occur. In order for any network to be established, an initial number of people must join together. The more people in the initial core, the more attractive the network is to others, the faster it will grow, and the lower costs will be for all concerned.

Figure 3.6 illustrates the problem. The analysis is essentially the same as the training cost problem. Because the firm improves the productivity of others as well as itself when joining the network, network subscribership will be lower than the most desirable.

In the initial stages of network development, this effect may be significant. The decision to join the network may be driven by who else is currently subscribing. An aggressive initial pricing policy, enabled by government sponsorship, can overcome this problem and enable a healthy initial subscriber base, and consequent rapid growth.

Figure 3.5

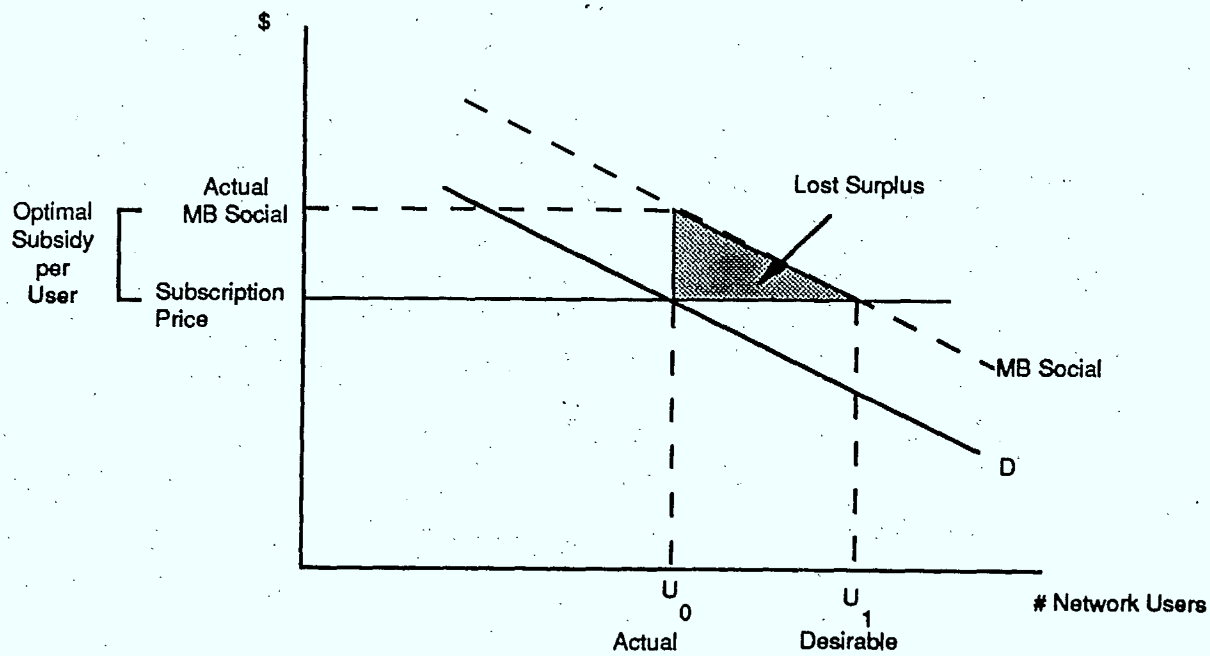
TRAINING EXTERNALITY



Under an expanding user-base potential network subscribers will tend to over-estimate the costs of maintaining staff expertise.

Figure 3.6

NETWORK
EXTERNALITY



Each Subscriber who joins the network
increases the value of
the network to others.

3.7 MARKET MAKING IN ELECTRONIC INFORMATION SERVICES

Creating a single point of access for electronic information services is a potential reason for government sponsorship.

As discussed previously, there is a vigourous industry developing in providing information services. The productivity impacts on R&D form using these services is significant, for those who are aware of them and are able to access them. However, the current use of these services is relatively low compared to the potential user base. Awareness of the degree of detail, analysis, and types of information available is low.

A handicap facing this industry is that there is no single "market place" where they may display their wares competitively, and where a user may encounter all the services available in passing. Under the current situation, it is not unusual to have subscribers of one service completely unaware that there are other services with different, and perhaps more appropriate, information available.

The network could provide such a market place by acting as a single point of access to these services.

Market making is a typical and legitimate government function. The creation of a marketplace by the private sector is difficult because it requires cooperation among competitors. If competitors do manage to cooperate to the extent of providing their own market place, it can lead to monopolization of the market place by established firms, and the foreclosing of market access to new competitors. Because of this problem, market making has been a historical government function.

3.8 INDUSTRIAL BENEFITS

The benefits to the IT industry of having a test bed have been described in the previous chapter. The question to be addressed is: Is there a reason for a government role in the provision of a test-bed? Why wouldn't the private sector provide its own?

Three potential reasons are:

- **The need for an independent host test-bed.**

  The test-bed should be run by an independent party to protect regular R&D users from loss in system reliability and to provide testers with a testing environment accepted as un-biased by their potential clients.

  An R&D network is ideal for this purpose because of its broad user base and the sophistication of its users. The broad user base gives the products the exposure they need, and the sophistication of the users will provide an ability to adapt and understand new service offerings.

- **The Setting of Standards**

  Successful provision of equipment or services on a government sponsored network is similar to meeting a standard of approval. If network operational standards are upheld and respected, then government sponsorship of the network will provide a means for Canadian IT providers to show third parties that their products meet certain quality and integration standards.

- **The R&D Externality**

  As discussed above, there are reasons to believe that Canadian investment in R&D is too low. Difficulties faced by R&D include imperfect intellectual property laws and difficulty obtaining financing.

  The rationales offered for the general support of R&D apply to the particular case of R&D by IT industries. The provision of a test–bed is a significant form of assistance for product development.

3.9 SUMMARY

In summary, potential reasons for government sponsorship of a high speed R&D network include:

- **Early Adoption of Productivity Enhancing Technology.** Private firms do not adopt new technology soon enough. Firms considering the adoption of new technology do not account for the benefit their example has in testing the worth of the technology for others. Government sponsorship of the network will allow the network to be established earlier and grow faster than it would be under private auspices. The benefits of early introduction expand exponentially over time.

- **Overcoming pricing constraints.** The network has significant fixed costs. Constraints on how users may be charged can mean that the network will be unable to fund itself in its early stages, even though the benefits to users exceed the costs of operation.

- **Promotion of Research & Development.** R&D tends to be under provided in all countries due to imperfect intellectual property laws and difficulties raising financing. The problem in accentuated in Canada by our branch plant economic structure. The R&D community in Canada is relatively small for a developed country. Government sponsorship of a high speed development network promotes and supports R&D without requiring project screening, and puts the R&D community in closer touch with other communities around the world.

- **Overcoming training cost barriers.** Initial adopters of new technologies, such as the users of high speed networks, overestimate training costs because they do not account for the benefits their own staff training has on enriching the labour pool for others. High perceived costs for training and maintaining staff expertise, can stunt or prevent network growth. Government sponsorship of the network can overcome this problem by permitting aggressive pricing of network services in the initial years.

- **Overcoming network externalities.** A common problem to all networks is the need to start with healthy initial subscriber base. This tends not to happen naturally because each firm will postpone joining until enough other firms join to make it worthwhile. Government sponsorship can allow aggressive pricing and a broad initial user base.

- **Market Making.** Governments have always had a valid role in providing market places where individual firms can compete and where customers may shop and compare. There is a growing need for a market place in electronic services, particularly for the growing industry in data base services. The high speed research network can provide a market place in the form of a single point of access for all these services.

- **Industrial Benefits.** IT product development requires assistance and support for the same reasons as Canadian R&D as a whole. The provision of an independent government sponsored test–bed by the network is an effective means of supporting a key Canadian industry. An open access publicly sponsored test–bed provides confidence to third parties in test–bed results and preserves domestic competition in the IT industry.

The above considerations are incorporated in the model used to estimate the dollar value of benefits and costs. A specific test is conducted of whether the above reasons are sufficient to collectively motivate government sponsorship. See Chapter 5 for the test description and Chapter 6 for results.

4. METHODOLOGY

An important aspect of this study is the requirement to specify the degree of confidence in the results and to present a report which is well–suited to a senior management target audience. It is our experience from reviewing many study reports that too seldom is the level of confidence or the range of results specified in the documentation.

While costs for alternative network speeds are relatively well known, quantifying and placing a dollar value on the benefits from a high speed network represented a serious challenge for this study. HICKLING's review of high speed networks in other countries revealed that no other country has attempted to do so. Those networks which have been implemented in the United States, Japan, and Europe, have gone ahead on a strategic basis without a quantitative assessment of benefits and costs.

To quantify benefits, some difficult questions must be answered. For example:

- How do we measure the worth of R&D, given the wide variety of projects undertaken in Canada and the intangibility of much of the results?

- How do we measure the impact on R&D productivity from a communication networks, given that they are only a vehicle for the wide variety of potential applications that must pass over them?

- How do we measure the industrial benefits from creating test–bed facilities for a myriad of potential IT products, many of whom are as yet unknown?

With the experience of other countries available, and with the unique expertise in dealing with uncertain data available through HICKLING's RAP process, Canada is in a unique position to be able to estimate and judge the worth of public investment in a high speed research network.

The key to benefits estimation is how to handle risk and uncertainty. It is possible identify the individual elements which determine the size of benefits, and to provide a model showing the quantitative relationship between the elements in a reasonable way. However, the numerical values of these decisive elements can never be precisely known.

HICKLING's RAP process is a method of quantifying risk. It produces average estimates and surrounding confidence intervals which reflect the true state of knowledge that exists. The knowledge that it incorporates includes both available statistical data, and the knowledge and experience of those most familiar with the problem at hand.

For example, RAP provides an average estimate of the internal rate of return to a project, **plus the probability that the real rate of return of the project will exceed the Treasury Board guideline of 10%.** (e.g. Project X may have a mean expected rate of return of 15%, but have significant uncertainty associated with some key determining factors, so that its probability of exceeding the treasury board guideline is only 75% (or a 25% percent chance of failing).

This chapter:

- Describes the Risk Analysis Process (RAP).

- Reports how it is applied to the benefit/cost measurement problem.
- Gives examples of RAP graphic outputs and describes the simple process of reading them.

The specific structure of the benefit/cost estimation model is detailed in Chapter 5.

4.1 ANALYSIS OF UNCERTAINTY

The fact that someone needs a forecast is itself evidence that there is uncertainty about the future and that there is some value in the ability to evaluate and plan for this uncertainty. The only certainty in forecasting is that every important assumption about the future will be wrong to some extent. Knowing this, how should decision–makers (and their technical advisors) deal with the risk of being wrong?

One common approach is to estimate "high" and "low" point estimates. This approach is often unsatisfactory, however, since it offers no guidance as to the relative likelihood of one estimate or the other. Moreover, "high" and "low" point estimates are typically constructed by assuming that all assumptions differ from their expected values in the same direction, an outcome that is just as remote as everything turning out exactly as projected.

Probability theory provides a way around the limitations of discrete point estimates outlined above. Probability measures the likelihood that an outcome will actually materialize.

To understand how probability theory can be applied in decision–making, consider a simple example. Before the advent of powerful computers, weather forecasters would simply provide their mean expectations – such as "we do not expect rain today". The decision on today's picnic would be easy – full steam ahead. Now the same forecast incorporates the probability for each causal factor in the determination of rain, and the forecaster announces that, "there is a 25 percent chance of rain by mid–afternoon". A more reasoned decision regarding the picnic is now possible. If the event involves costly logistics for hundreds of people, a rain date might well be considered. In the past, provision for risk was not possible and a good many dollars—not to mention tempers—were lost.

Risk assessment, while not in common use, is by no means new, and has been used to assess long–range investments by public agencies and private firms alike. By attempting to assess the uncertainty of each of the key factors that might influence a major investment decision and incorporating this uncertainty into the analysis, the resultant forecast will not offer a single "take it or leave it" answer. Rather, information can be presented that actually reflects the uncertainties involved—and how they might influence the forecast.

4.1.1 What is RAP?

Risk Analysis Process (RAP) is an integrated and automated set of computer programs developed by HICKLING for evaluating the uncertainty inherent in forecasts or other applications.

RAP is characterized by five key attributes:

- it deals with uncertainty and risk using advanced statistical techniques,
- it allows sound management intuition to be applied quantitatively in the evaluation process,

- it depicts the economic structure in the real world,
- it helps clarify and sharpen understanding of the critical factors affecting the economic environment, and
- it facilitates systematic evaluation and consensus building on controversial matters.

RAP has been previously used in applications including evaluating the economic impact of icebreaking; assessing alternative transportation strategies for disabled persons; examining forecasts of airport capacity and demand; and predicting the impact of weapon threats on military vehicles.

4.1.2 How RAP Works

Each variable of importance to the analysis of a given problem is assigned a range, and probability distribution, reflecting the underlying uncertainty. These estimates are then combined to provide an estimate of the probability that the output variables of interest vary from their expected value.

Specifically, the risk analysis process involves three steps.

1. **Development of the structure and logic models.** This step establishes the methodologies and ascertains which variables and assumptions must be considered in the decision problem.

2. **Development of initial parameter values and ranges.** In this step, estimates and ranges are developed for each variable and assumption identified in Step 1 and recorded in special sheets like those found in Appendix C. These estimates are based on the consulting team's statistical analysis of actual data and subjective judgement drawn from experience in the field. Their experience, training, "street–wise" judgement and knowledge of relevant facts and issues provide a database and analytical process which would be impossible to model. The ranges elicited and recorded on the data sheets reflect the initial subjective assessment that the actual value lies within the stated range with 80% probability (i.e., the upper and lower ten percentiles are identified).

3. **Simulation.** Once the experts have completed their work, the ranges for each assumption are transformed within RAP into input probability distributions. And once final distributions are generated for all assumptions and variables, they are combined using probability theory to yield a probability distribution for each output variable of interest. This step involves a statistical technique called Monte Carlo Simulation. This procedure is described below.

4.2 RAP MONTE CARLO SIMULATION

Figure 4.1 illustrates the how the RAP Monte Carlo simulation works. From the logic and structure models of step 1, a mathematical model is derived relating the value of a project to all its key determining factors. The mathematical model relates input values (A,B,C,D) in the diagram, to output values (F). The diagram shows the equation in generic form as F = f{A,B,C,D}. The diagram is a simplification. The actual model has many inputs and outputs.

For any given set of input values, there will be one output value. However, the precise values of the inputs are unknown. Instead, the expert review process has provided estimates of the mean, and the likely range of variation of each input value. The RAP computer program generates a probability distribution of the input value from the mean and range.

The RAP computer program chooses a value for each input in randomly according to the probability distribution it has constructed. Once it has generated a value for each input, it calculates the output, in this case the net present value of the project. This process is repeated many times by the computer, until an overall picture of the distribution of the output values is generated.

This repetition by random sampling is called a Monte Carlo process. It has several advantages over other approaches:

1. A picture of the total risk is generated. Techniques such as sensitivity analysis can only identify how each factor affects the value of a project individually. They cannot provide an overall estimate of the likelihood that the project is a paying proposition.

2. Probability distributions are graphic. It is possible to tell at a glance the degree of risk associated with results.

3. It allows for a true representation of uncertainty among inputs. Mathematical techniques which short–cut the process must use symmetrical distributions (such as the well known "Bell Curve") to represent uncertainty in the inputs. In reality, uncertainty is usually skewed. The range of high values may be quite uncertain, while a minimum value on the low end may be well understood. RAP allows skewed distributions.

4. Where numerical data is absent, the wisdom and experience of experts familiar with a process may be used to quantify the expected values and range of uncertainty of input values. Experts on the panel need not be familiar with probability or with all the facets of a problem. They need only know their own area well.

4.3 INFORMATION GATHERING

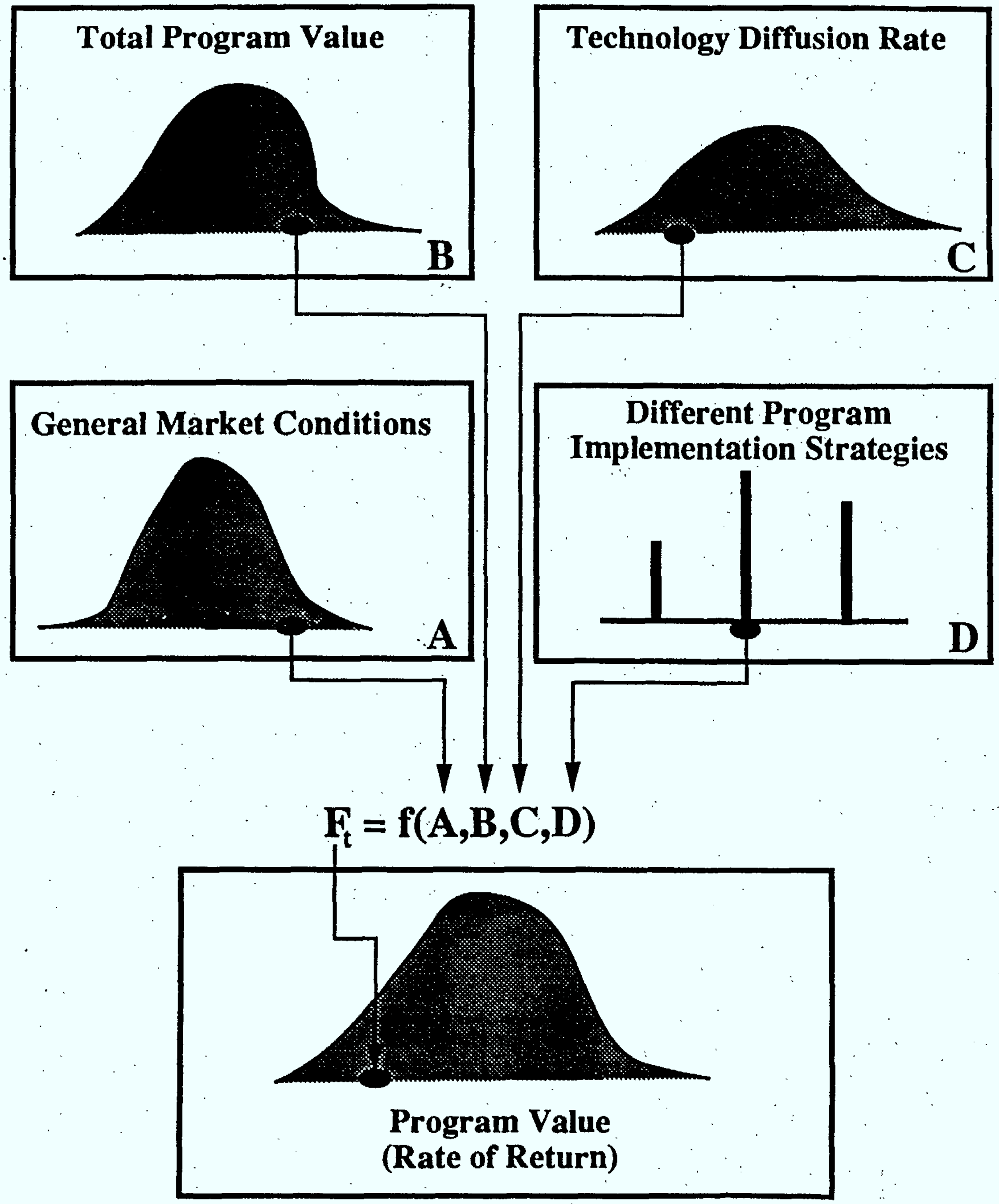
An extensive research and information gathering effort was undertaken by the study team to prepare for the setting RAP values. There was extensive consultation with experts and users in the field.

Four instruments were used by the study team to identify potential participants and obtain information on their needs and objectives:

- Expert Panel Sessions;
- In–person interviews;
- A questionnaire distributed via the Netnorth and CDNnet networks; and
- Telephone interviews.

Every effort was made to contact as many potential participants as possible. In fact the project team received direct input from more than 400 individuals who took part in one of the four survey instruments identified above. The project team has discussed this network initiative with government officials in every province and territory in Canada, and also with Federal Government representatives (eg. NRC, DOC, EMR, GTA and CRTC).

Monte Carlo Simulation: Combining Probability Distributions



A full description of the consultation process may be found in Volume A.

Final values were set by a review panel of team members.

4.4 READING RAP RESULTS

RAP produces three interpretations of a given input or output:

- A probability distribution of the value for a given year.
- A decumulative distribution of the value for a given year.
- A time series graph showing the mean expectation and the band of uncertainty for the value over time.

Example outputs are provided in Figure 4.2. The example value is drawn from the actual output of the cost/benefit analysis. It is the average percentage increase in the productivity of research and development produced by the introduction of a high speed network. The year chosen for illustration is the 20th year of network operation, the last year covered by the model.

Probability Distribution

The title of the top diagram identifies it as the productivity gain under the ISTC network for year 20. The phrase "mean value 2.99E–02", means the average expected productivity gain is 2.99%, or .0299 in decimal form. "E–02" means move the decimal point over two places to the left. The variable name in brackets (AVPROD) is the acronym used in the model equations and may be cross referenced in the Appendices.

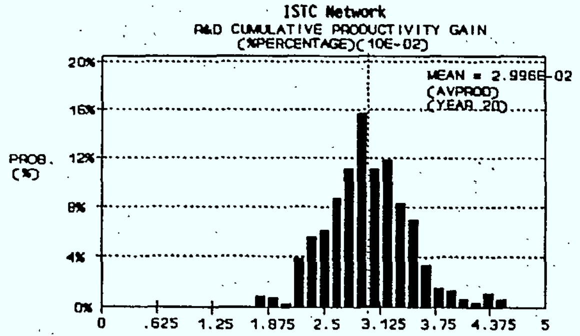
The bottom axis shows the range of values for the productivity increase. The values on the axis range from 0% to 5%. The "10E–02" in the title means "move the decimal point on the axis two to the left. If the units were millions of dollars, it would read "10E+06" indicating that 6 zeros had to be added. The apparent complication of these exponentials is necessary to keep the numbers on the bottom axis big enough to read. The position of the mean (2.99%) is indicated by the vertical dotted line.

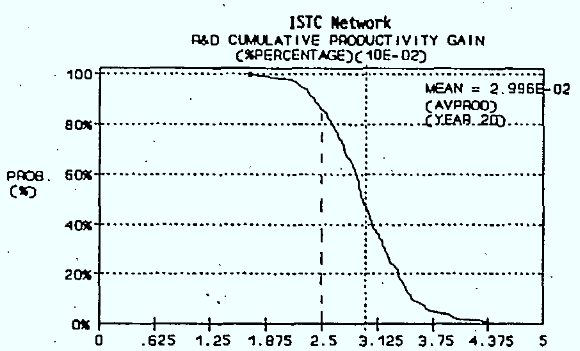
The black bars are a histogram showing the probability distribution of likely values. The actual range of values is divided into 20 equal sized intervals. The height of the black bar indicates the percentage of values falling into each interval. The most likely value range to occur is just below the mean with a frequency of approximately 16%. The positioning of the histogram shows that the probability of the productivity impact being less than 1.8% or more than 4.5% is negligible. The shape of the distribution shows a normal central tendency (one "hump") and therefore a stable value around the mean of 2.99%.

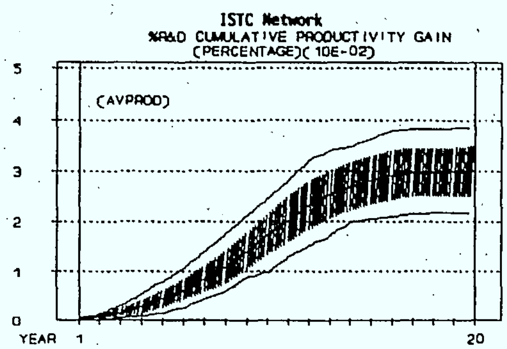
Decumulative Probability Distribution

The middle figure presents the same information as the probability distribution in a different way. The horizontal axis still represents the productivity impact. The "s" shaped curve displays the probability that a given value for the productivity impact will be exceeded. For example, the probability of obtaining a productivity impact of greater than 2.5% is a little over 80% (very likely).

FIGURE 4.2
SAMPLE OUTPUT







Time Series

The top and middle graphs showed the probability distribution of productivity impact for one year (year 20). The bottom graph is a time series displaying information on all 20 years. The solid line in the centre shows how the mean (or average) productivity impact grows over time as the network matures. The solid outside lines show low and high estimates based on a 90% confidence interval. (There is a 10% probability that the productivity impact will fall outside the lines). The inner shaded band represents a range of one "standard deviation", and is a measure of the instability around the central value. We can see from this graph that in year 20 the 90% confidence interval falls between a 2% and 5% productivity impact.

Precise Numbers

In addition to graphics, RAP reports precise numbers for any level of confidence desired. Typically, text accompanying graphs in this volume will report an 80% confidence interval, that is, a low value which is 90% likely to be exceeded and a high value which is only 10% likely to be exceeded.

5. BENEFIT/COST MODEL

To estimate the benefits and cost of a high speed R&D network, it is necessary to derive a mathematical model which reasonably represents how benefits accrue. This chapter:

- Describes the general framework and assumptions of the model
- Outlines the major principals and assumptions applied in each part of the model
- Explains the incremental tests comparing the ISTC network to the lower speed option currently represented by the reference case.
- Explains how the potential rationales for government sponsorship have been incorporated into the model.
- Explains how the test for government sponsorship is conducted.

This chapter describes the principles and underlying relationships employed by the model. The appendices to this volume contain a mathematical description of the model, a key to variable definitions, probability ranges assigned to each variable, and the reasoning behind the assignment of probability ranges.

5.1 STRUCTURE OF THE MODEL

The estimation of benefit/cost is performed over a 20 year period. 20 years represents the time frame over which the network is expected to mature. Maturity occurs when:

- The user–base subscribing to the network accounts for a stable proportion of the R&D in Canada.

- The applications provided on the network have reached a level of sophistication that provides the bulk of the productivity impacts on R&D that may be expected from them.

- The cumulative percent increase in Canadian IT sales caused by test–bed availability has reached a stable maximum.

Benefits and costs beyond year 20 are assumed to be constant.

5.1.1 Network Philosophy

It is assumed that if the high–speed network is undertaken it will be under the joint rationales offered in Chapter 3. This means that government sponsorship will be used to promote rapid expansion of the network in order to introduce to encourage the rapid adoption of productivity enhancing applications in Canadian R&D and other sectors of the Canadian economy. A general policy of accessible pricing, and investment of staff time in service development is assumed.

5.1.2 Benefits Accounted For By the Model

The model accounts for the benefits of providing an IT test–bed to Canadian industry and domestic consumers, and for productivity impacts on research and development for five of the six application groups defined in Chapter 2. The five application groups are:

1. Time–slipped Communications (E–mail & Bulletin Boards)
2. Virtual Terminals
3. Large File Transfers
4. Real–time Communications (Video Conferencing)
5. Databases

The impacts of other applications, including remote education and distributed processing, have not been included. The benefits of these items may be significant, but expert panelists felt they were difficult to quantify.

5.1.3 R&D Expenditure Assumed Constant

In addition, expenditure on R&D was assumed to be a constant proportion of the Canadian Gross Domestic Product. This is a conservative assumption, since increased productivity in R&D caused by the network should lead to an increase in expenditure on R&D. Like any other product or service, when the price falls or the worth per dollar increases, more is demanded.

The proportion of benefits excluded by holding R&D constant is not expected to be large for two reasons.

- Low percentage increases in productivity are being considered. For example a 3% increase in R&D productivity may lead to an increase in R&D expenditure of the same order (3%). Underestimates of benefits will be similar.

- In order to have an impact on industrial investment relative to other forms of investment, R&D productivity must not only advance, it must advance faster than the productivity of other types of industrial investment. Under normal circumstances, productivity tends to advance in all sectors of the economy as time passes.

5.1.4 Conservatism in the Model

Because of the assumption of R&D as a fixed proportion of GDP, and because of the exclusion of education, the social sciences, and the humanities, as well as some minor technical applications, the net benefits estimates by the model are conservative in nature.

5.1.5 The Eight Modules

The model is divided into eight separate modules:

- **R&D Benefits.** Measures the benefits of a high–speed network to R&D users.

- **R&D User Costs.** Measures the costs to R&D users to train staff and maintain the hardware necessary to use the system.

- **R&D Willingness to Pay.** Measures the likely amount of funds that could be raised through user charges.

- **IT Costs & Benefits.** Measures the costs and benefits of test–bed use to the Canadian IT industry.

- **IT Willingness to Pay.** Measures the likely amount of funds that could be raised by charging the IT industry for test–bed use.

- **Network Costs.** The cost of providing the network.

- **Net Benefits.** The net present value and rate of return on investment of the ISTC network.

- **Incremental Benefits.** The net present value and rate of return on the incremental funds invested to achieve the ISTC network over the lower–speed option currently represented by the reference case.

The principles employed by each of these modules are described in this chapter. Equation structure and an alphabetical listing of variable names is provided in the Appendices.

5.2 TESTING FOR INCREMENTALITY OVER THE REFERENCE CASE

The model structure for the ISTC network and for the reference case is the same. The two options are assessed differently by assigning different values to the input values. To find the incremental costs and benefits of the ISTC network over the lower speed network, a RAP session is run twice, once for each case. The benefits and costs of the reference case are subtracted from the benefits and costs of the ISTC network to find the incremental benefits and costs.

The key differences in input values assigned to the reference case are:

- **No IT benefits.** The reference case is assumed to have no IT test–bed benefits. In addition, because it represents a lower position on the technology curve (see Chapter 1), it does not provide high enough network speed to test products for new and emerging technologies.

- **Later start date for some applications.** The start date when some applications are available through the reference case is later than through the ISTC network. Depending on the application, this is due to the reference case achieving the required network speed at a later date or lower staff time available to promote the introduction of new applications.

- **Later maturity date for some applications.** The date when applications can be expected to achieve their mature form (and consequent mature productivity impact) is later for the same reason as the later start dates.

- **Lower participation.** The proportion of R&D expenditure represented by subscribers is expected to be lower under the reference case. Private sector participation is expected to be substantially lower because of the lower speed, academic focus, and likely pricing structures of the reference case. Government and institutional participation is expected to be somewhat lower with the lower speed and the loss of interaction with the private sector.

- **Lower costs.** The costs of the reference case are expected to be significantly lower than the ISTC network. Higher network speeds plus staff time for ensuring an accessible system with a good menu of applications are the principal reasons for the ISTC network being more expensive.

It is expected that the reference case will ultimately offer the same applications with the same productivity impacts at maturity. The increased benefit of the ISTC network is to have these applications:

- introduced sooner,
- reach maturity sooner, and
- apply to a wider user–base, particularly in the private sector.

These benefits are combined with the IT test–bed benefits available only to the ISTC network to establish total incremental benefits of the ISTC network. These benefits are then compared to the additional cost.

If incremental benefits exceed incremental costs, then the additional expenditure required by the ISTC network over lower speed network alternatives is considered worthwhile.

5.2.1 Neutrality of Productivity Impact Estimates

It is important to note that the assessment of mature productivity impacts by applications are unimportant to the assessment of incremental benefit, since the model accords both the ISTC network and the reference case with the same values.

5.3 TESTING FOR GOVERNMENT SPONSORSHIP

If a high–speed network proves cost beneficial, the question still remains whether there is a need for government sponsorship. Chapter 3 identified a number of reasons why a privately offered high speed research network might not be able to initially raise funds to sustain itself.

As with the testing of incremental benefits, timing is a key consideration. As technology advances and costs fall, a privately offered network might become feasible. However, delay of network introduction of 5 or 10 years would significantly reduce the benefits to the Canadian economy.

The test applied by the model is to ask:

"At what point in the proposed network life are revenues likely to exceed costs?"

The significance of this question to the feasibility of a privately offered network requires some elaboration. At issue is the "free–rider" effect

5.3.1 The Free Rider Effect

From a private sector perspective, investments are not usually required to cover their operating costs immediately. Losses in initial years of operation are expected to be recovered in later years as a business grows.

An exception occurs when a private firm must pay costs not just for itself, but for all firms. If the first firm in a market must pay to educate consumers and develop technology, then subsequent firms in the market receive the free benefit of the first firm's "market making" efforts. This is the "free rider" effect.

If the free-rider effect is significant, it can delay or prevent the introduction of a new service. A private firm who offers a high-speed network too early will be burdened by the costs of developing applications and building user familiarity. Later entrants to the market will be able to under-price the first firm because they will not be burdened by the accumulated debt of these "market making" efforts. Recall that application development is only partially protected by intellectual property laws.

Therefore, if the break-even year of a privately offered network is too far in the future, private sector firms will not undertake the project even if total benefits exceed total costs. If they do so, they will be paying a substantial part of the costs, but other firms will be reaping the benefits.

5.3.2 The Test for Government Sponsorship

Since a long wait until a break-even year indicates that the private sector is unlikely to under take a high speed research network, this was chosen as a test for government sponsorship.

If the high-speed network benefits exceed their costs, and if the break-even year is significantly in the future, then government sponsorship is called for.

The gap between potential revenues and expenses is plotted over the 20 years by the model to determine the likely break-even year. (See results, Chapter 6)

The intervention rationales, as identified in Chapter 3, are incorporated in the structure of the individual modules. A summary of how this is done is given after the modules have been described (below). The modules include "willingness to pay" modules which assess the likely amount of revenue that can be raised from R&D users and IT test-bed users.

5.4 R&D BENEFITS MODULE

The network will have its impact on Canadian research and development by improving the value of R&D through greater specialization and collaboration, and reducing the costs of R&D through shared facilities, information services, e-mail, etc. (See Chapter 2) The improved value of research and the cost savings may be captured by one measure: productivity.

Benefits to R&D were measured in terms of productivity gains. Productivity is defined in its broadest sense as:

$$\text{Productivity} = \frac{\text{The \$ Value of Outputs}}{\text{The \$ Value of Inputs}}$$

If an application offered on the network reduces costs by an average of 10%, or increases the value of R&D product by 10%, the productivity impact in either case is approximately 10%. If it does both, the impact is approximately 20%. If there is a 10% productivity impact on total R&D expenditure of $100,000, then the benefit is $10,000.

The advantage of this approach is that, in concept, it captures all benefits without having to consider the actual worth of individual R&D projects. R&D projects may be aggregated into large groups by adding up the total expenditure.

For any given year, R&D benefit was estimated according to this identity:

$Benefit = ($R&D Expenditure)*(% Subscribing to Network)
*(%average cumulative productivity gain)
*(adjustment for underspending on R&D)

or, in the terminology of the model

$Benefit = ($R&D Expenditure)*(%Uptake)
*(%Average Productivity Increase)
*(Social Benefit Multiplier)

The social benefit multiplier accounts for the known problem of underspending on R&D due to imperfect capital markets and intellectual property laws (see Chapter 3). In brief, if the social benefit multiplier is 1.1, this would mean that an additional 1$ spent on R&D currently yields $1.10 in benefits.[5] In this case, a 10% increase in productivity would be worth eleven cents, not ten cents, on the dollar. The expected value of the social benefit multiplier was set at 1.1 or 10%, with a lower bound of 1.0 (0%) and an upper bound of 1.2 (20%).

Average productivity impact was determined by summing up the average productivity impacts of each application group on each user group. As identified in Chapter 2, there are 5 groups accounted for by the model:

1. Time–slipped Communications (E–mail & Bulletin Boards)
2. Virtual Terminals
3. Large File Transfers
4. Real–time Communications (Video Conferencing)
5. Data–Bases

User groups were defined in Chapter 2 as:

1. Private Sector
2. Government
3. Institutions

5 application groups and 3 user groups meant a total of 15 separately identified productivity impacts over 20 years. The productivity impact of each application on each user group is given by the identity

Average Productivity Increase = (%Regular users of application)
*(Productivity increase of application)

or, in model terminology

Average Productivity Increase = (%Penetration)
*(Productivity increase of application)

Productivity impacts varied among user groups primarily because of a greater expected need for communication and collaboration in government and institutional R&D than in the private sector. The expectation is based on the greater proportion of primary, pre–competitive research in government and institutional organizations.

[5] i.e. Marginal benefit exceeds marginal cost. See Figure 3.4.

Note that productivity increases employed by the model are not annual increases, they are cumulative. For example if productivity impact is 2.4% in year 9 and 2.5% in year 10, the cumulative productivity impact in year 10 is 2.5%, not .1%.

Productivity impacts of applications are presumed to start small and increase over time as the technology of the application matures and as network speed advances. Figure 5.1 shows how productivity increases grow over time. PRBAS is the initial productivity impact and PRMAT is the mature productivity impact. TSTART is the first year the application is offered and TFIN is the year the application reaches maturity in its productivity impact.

Figure 5.2 compares the treatment of productivity gains between the reference case and the ISTC network. The illustration shows the most extreme case, a later start date and a later maturity date. Some applications are assumed to start at the same time, such as electronic mail. For the actual probability ranges assigned, see Appendix C. Note that both the reference case and the ISTC network achieve the same level of mature productivity impact.

Uptake rates, the proportion of R&D expenditure represented by the subscriber base, are illustrated in Figure 5.3. A separate time path for uptake rate was established for each user group. UPBAS is the beginning uptake rate and UPMAT indicates the mature proportion of R&D expenditure represented by network subscribers. TUPST is the starting time, which was set to year 1 in all cases. TUPFIN is the year network participation reaches maturity for that user group.

Figure 5.4 compares uptake rates for the reference case and the ISTC network. Uptake rates for the ISTC network are presumed to begin higher and mature higher due to greater private sector participation and higher network speeds. They are also expected to mature sooner because of higher network speeds and greater staff available staff time for network development.

5.4.1 Large Numbers

It should be noted that the volume of expenditure on Canadian R&D in 1989 is estimated as approximately $8.3 billion. Any increase in productivity will have a significant impact. For example, a 1% gain in productivity would be worth $83 million per year.

5.5 R&D USER COSTS

Costs to R&D users, excluding network fees, are identified as training costs and hardware costs. Training costs represent the initial amount of time R&D workers must spend to fully familiarize themselves with the network and the network applications they wish to use. The time may be spent in the process of carrying out network tasks, or it may be spent in initial study. For example, the cumulative time spent may be a week over the course of the first year an R&D researcher encounters the network.

Hardware costs are driven by the number of users on the system. Users are assumed to be the same proportion of R&D workers as the proportion of R&D expenditure represented by subscribers. A hardware depreciation and replacement cycle of 3 years is assumed, so that older technology is constantly being replaced with newer technology, advancing in parallel with then network. Note that this is consistent with the three year replacement cycle assumed in estimates of network cost used in other volumes of this study.

Figure 5.1

PRODUCTIVITY IMPACT OF APPLICATION GROUP A ON USER GROUP I

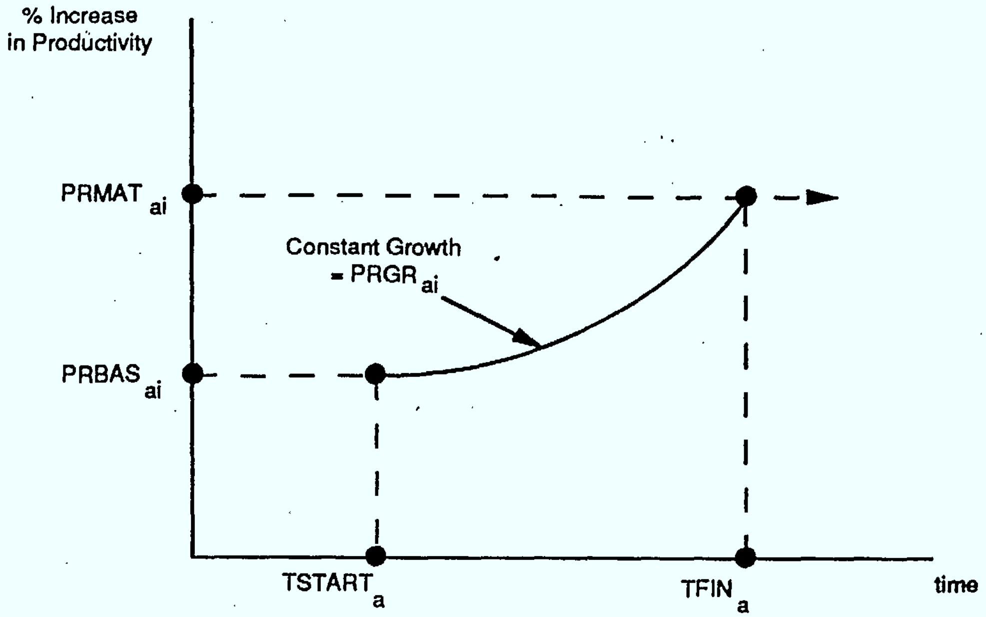
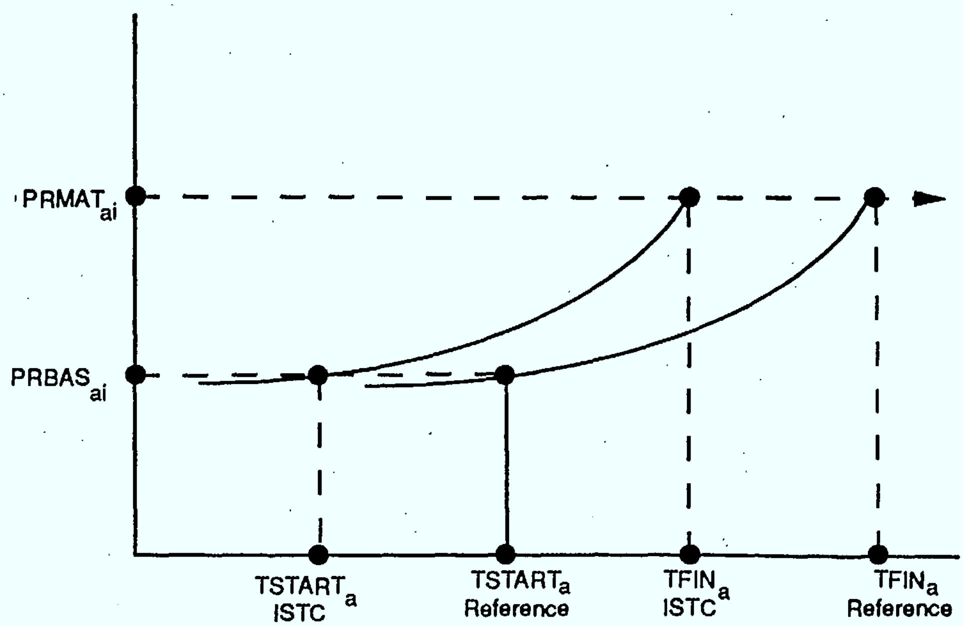


Figure 5.2

PRODUCTIVITY IMPACTS
ISTC NETWORK AND REFERENCE CASE



34

Figure 5.3
GROWTH IN UPTAKE RATES OVERTIME
FOR USER GROUP I

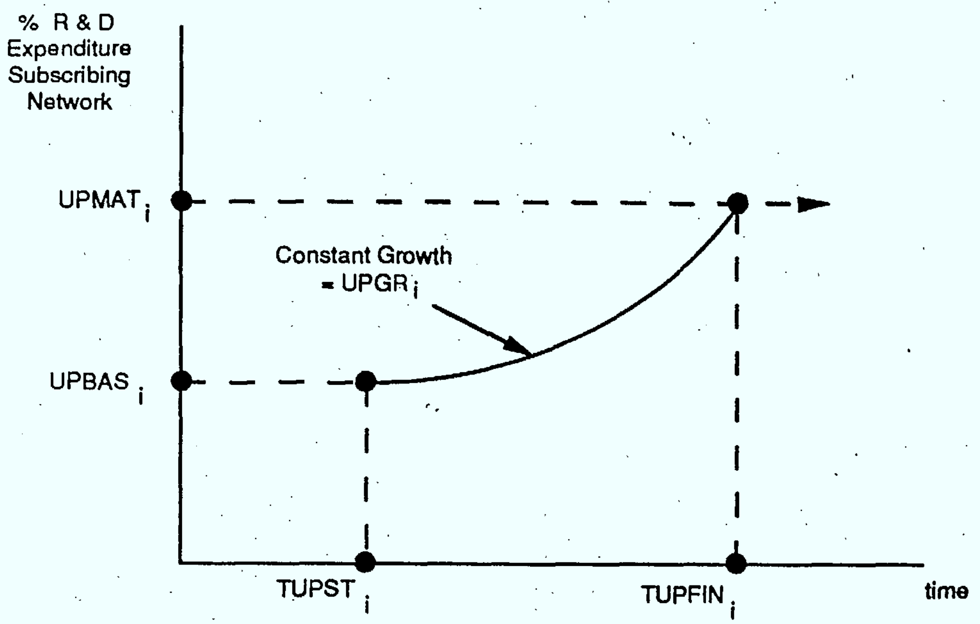
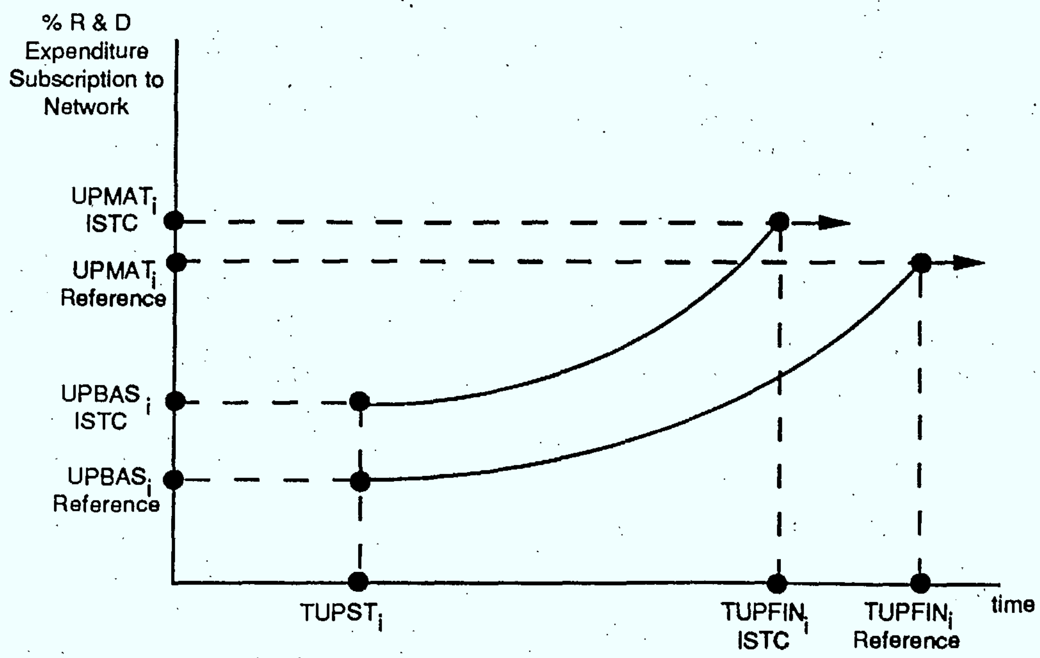


Figure 5.4
GROWTH IN UPTAKE
ISTC NETWORK AND REFERENCE CASE



5.6 R&D WILLINGNESS TO PAY

Willingness to pay was treated separately according to user group. The ability to raise revenue from government R&D organizations and institutions was considered to be different from the that of the private sector. While the private sector can be expected to pay according to the value of the service, public sector and institutions face fixed funding constraints. The private sector problem is considered first.

The maximum R&D users would be willing to pay is the full value of the productivity gains they receive. However, extracting this gain in user fees would require knowing exactly how much each R&D user benefits from the network and charging them an individual price. This is not usually feasible.

In most markets, users are charged the same price for the same service, whether it is a fixed fee, by level of access, or by the hour. This means that most users are receiving value in excess of what they are paying. The excess value, or "consumer's surplus", varies according to the individual.

Total productivity gains to users may therefore be divided into two parts, the part that is paid back to the network in user fees, and the remaining "consumer's surplus".

Revenues available from users may therefore be expressed as a proportion of productivity gains. The proportion is less than one because of the inability to charge each user the exact price they are willing to pay. This concept is illustrated in Figure 5.5. The demand curve represents the number of subscribers at each network subscription price. The lower the price, the more firms who find it worthwhile subscribing. The total area under the demand curve and to the left of the current number of subscribers can be shown to be equal to the productivity gains created by network access. Total revenue is equal to price times the number of subscribers, or the shaded area (area b). The area above price and below the demand curve (area a) is the consumer's surplus.

Together, areas (a+b) represent productivity gains. The ratio of [b/(a+b)] is the willingness to pay out total productivity gains.

5.6.1 Elasticity of Demand

The ratio of (a/(a+b)) can be shown to depend on a value called the "**elasticity of demand**".[6] The elasticity of demand is the percentage change in subscribers that would come from a 1% drop in subscription prices.

The calculation of willingness to pay in any given year is therefore calculated as

Willingness to Pay = ($Productivity Gains – R&D User Costs)*(Reduction Factor)

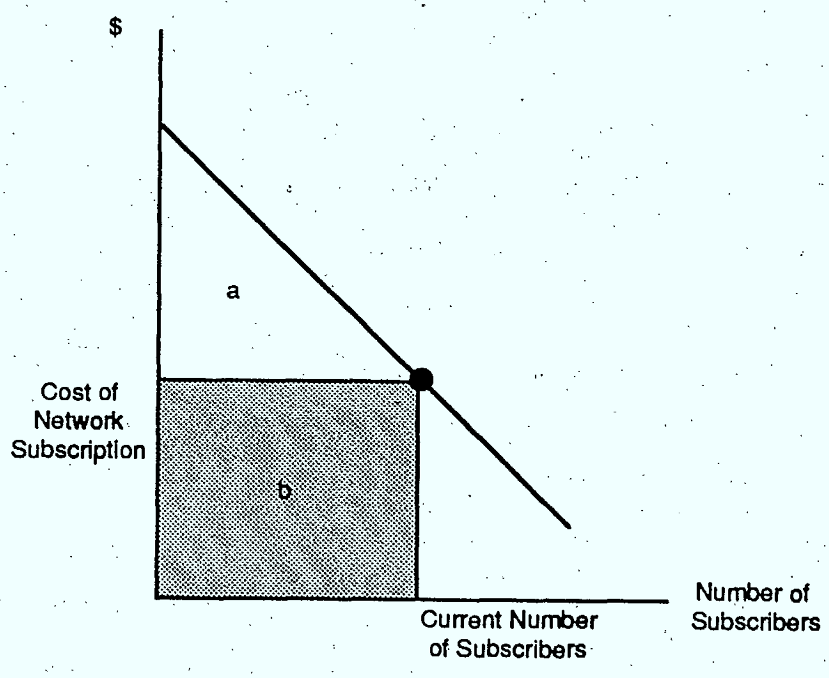
where the reduction factor is a function of elasticity of demand. At higher elasticities (more price responsive demand), the reduction factor is lower.

Elasticity of demand is a policy variable, in that it changes with the price level charged. At high prices, demand elasticity tends to be high. A small percentage reduction in price can have a big effect on quantity (e.g. going from 1 subscriber to 2 is a 100% increase). At low prices, demand elasticity is low.

[6]For estimation purposes, linear demand curves are assumed.

Figure 5.5

R&D WILLINGNESS TO PAY



It can also be shown that revenues are maximized when the elasticity of demand equals 1. However, we are assuming that government sponsorship will be used to price aggressively in the initial stages, so that a lower range of elasticity values is assigned in the model.

Finally, note that no specific pricing structure is assumed in this calculation. It is only assumed that, however charges are applied and the market segregated, pricing will not be individualized by user, and will be held down to promote early growth in the user–base.

5.6.1 The Training Externality

A firm perceives its training costs in two parts. There is the initial cost of training all relevant staff. Then there is the cost of training new or replacement staff. The cost of replacement training depends on the probability that new hires will already be familiar with the network. The more likely new hires are to be familiar with the network, the lower the expected cost of having to train a new hire. Therefore, as network participation rises and familiarity with the network extends through the R&D labour force, training costs perceived by the individual firms fall.

Chapter 3 identified the problem of firms overestimating the cost of maintaining staff skills to use the network (See Figure 3.5). The problem occurs during network growth if each firm fails to account for the impact of new firms on enriching the proportion of network–trained R&D workers in the labour force.

To capture this effect, R&D perceptions of the proportion of the labour force familiar with the network are assumed to be based on participation in the network in the previous year. In contrast, firms with foresight would base their expectations on a rising trend over current and future years. The myopic assumption that the proportion of the labour force familiar with the network remains fixed leads to higher perceived training costs and a lower willingness to pay.

5.6.2 Willingness to Pay by Institutions and the Public Sector

The model assumes that the public sector and institutions face funding constraints, so that their willingness to pay is relatively fixed, and only likely to increase as a greater proportion of the public sector and institutions subscribe to the network.

It was assumed that the current level of revenues envisioned for CAnet represents the limits of willingness to pay under the initial subscriber base. CAnet revenue estimates are currently available only as a rough estimate, on the order of $1.3 million annually in the first three years. Contributions beyond the size of the user base anticipated for the reference case in year 3 are based on a proportional increase in the size of the user base, as measured by the total amount of R&D budget of subscribers. This standard of reference is applied to both the reference case and the ISTC network, so that if the ISTC network has a 10% larger public and institutional user base in year 3, its expected revenues from these sources range around 110% of $1.3 million.

5.7 IT TEST-BED BENEFITS AND COSTS MODULE

The benefits of a test–bed for Information Technology firms is measured through expected impact on sales volume. The are four advantages of using sales impact as a basis for measurement:

- The base number, current IT sales, is obtainable.
- The expected impact on future IT sales can be estimated by IT users with greater accuracy and understanding than more complex concepts.
- The impact on a the great variety of current, potential, and as yet unknown products can be aggregated through total sales impact.
- It is possible to develop valid estimates of benefits to the economy by combining sales impact with relatively little other data.

To apply the sales impact, the industry was divided into two groups; equipment providers and service providers. The proportions of industry sales falling into the two groups was obtained using those IT firms registered on the CANTECH Database of advanced technology manufacturers and service providers.

Figure 5.6 illustrates how the model estimates sales impacts. Sales impact begins at year TITST and ends at year TITFIN. The initial sales impact is low at INCBAS, and grows to a mature level (INCMAT) as the IT user base expands, and as the intensity of its use increases.

The mature sales impact was derived by applying conservative assumptions to a survey of IT users (see Volume A). Survey respondents were asked what percentage impact they expected access to the network to have on their sales. Because the survey sample was biased in favour of those with high network familiarity, the responses were assumed to be representative of the upper bound of likely impact at maturity.

41% of firms representing 29% of sales responded that their sales would be positively affected by access to the network. Respondents were asked for a low and a high estimate on the percentage impact on sales. Weighting by dollar sales volume, the average increase for high was 1.34% of total sales (both affected and unaffected), and an average low estimate of 0.58% of sales. These values were used to set the probability distribution for the mature sales impact (13 to 17 years after the first year of network operation).

In brief, the current expectations of those responding to the survey was taken as a guideline for the long–run mature impact on sales.

The initial impact on sales was established based on an expected lag between the first year of network operation and the year a significant volume of products would be available for testing. Given a typical lag of between 3 to 5 years from product development to testing, a four year lag was assumed. Significant sales impacts therefore begin in year 5.

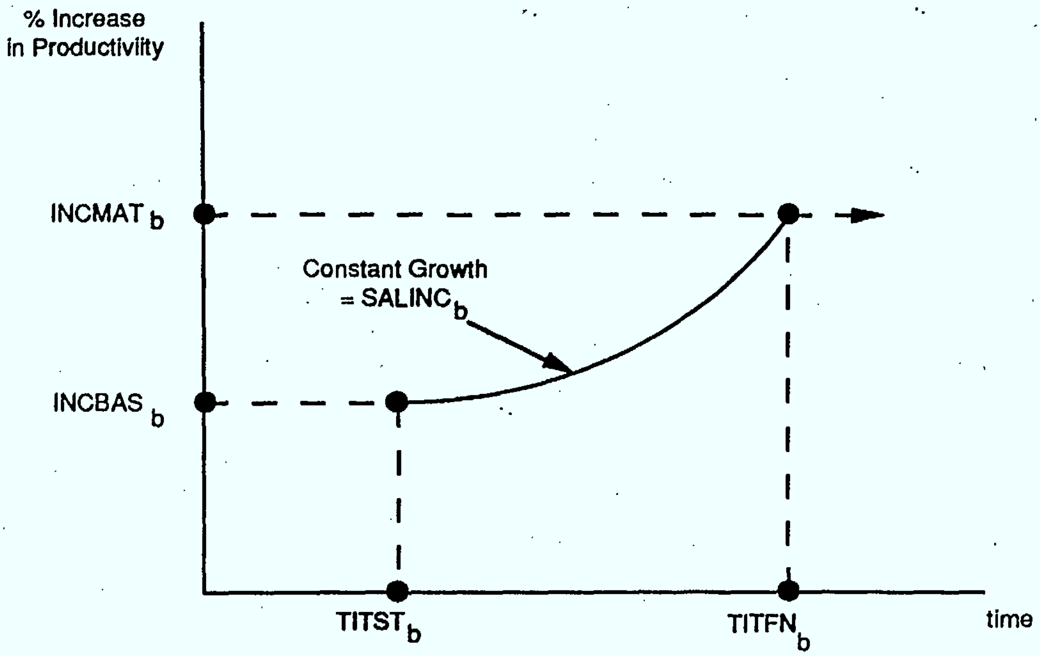
The initial sales impact was judged conservatively to be approximately two orders of magnitude (1/100) less than the mature sales impact, with growth to occur exponentially. The two orders magnitude represented:

- The initial base of test–bed users being a fraction of the mature participation expected from the industry.
- Initial use of the test–bed being less than mature use.

Little data was available for an initial sales impact, since the survey results were interpreted as being typical of the mature impact.

Figure 5.6

% IMPACT ON IT SALES
FOR INDUSTRY GROUP B



5.7.1 Converting Sales Impact to Net Benefit

Increases in sales are not themselves net benefits. The increased sales must be paid for through increased costs. Benefits from increases sales come in two forms:

- An increase in the net returns to IT firms and their employees.[7]
- Consumer's surplus. The excess of the value of the new or improved products over the price paid by buyers.

Figure 5.7 illustrates the benefits of an increase in IT sales through the introduction of a new product. The supply curve shows the quantity of the product produced at different prices. It rises, because more will be offered by producers at a higher price. The demand curve shows the quantity that will be purchased at each price. It declines because lower prices attract more buyers. The market price and quantity will be at P_0 and Q_0, where the two curves cross. The increase in IT revenue is equal to price times quantity, or the areas b, and c. Area b can be shown to be the increased profits to IT firms and their employees. Area a is the net gain by consumers, the excess of their demand price over the actual price.

Total benefits are equal to (a+b), with some adjustments. Area (a), the returns to buyers, includes both domestic and foreign buyers. To restrict area (a) benefits accruing to Canada, area (a) is reduced in the model by the proportion of IT goods and services exported. This is a significant amount since the IT industry is a significant source of Canadian exports. The proportion of IT sales exported was obtained from the IT survey so that it could be tied to the sources of sales increases. Percent of sales represented by exports was 64.5% for all those responding, and 34.4% for just those who indicated a strong sales impact. These two numbers were used to indicate the range for the probability distribution assigned to this value.

The sum of areas (a) and (b) for all products can be estimated using the expected increase in total revenue for all products and estimates of demand and supply "elasticity" (the responsiveness of quantity demanded or supplied to price). This approach was employed.[8]

In summary, IT benefits to the industry and industry customers is based on the following identities:

Consumer Benefits = ($ Increase in Sales)*(Consumer Benefit multiplier) *(Proportion of Sales made Domestically)

Producer Benefits = ($ Increase in Sales)*(Producer Benefit multiplier)

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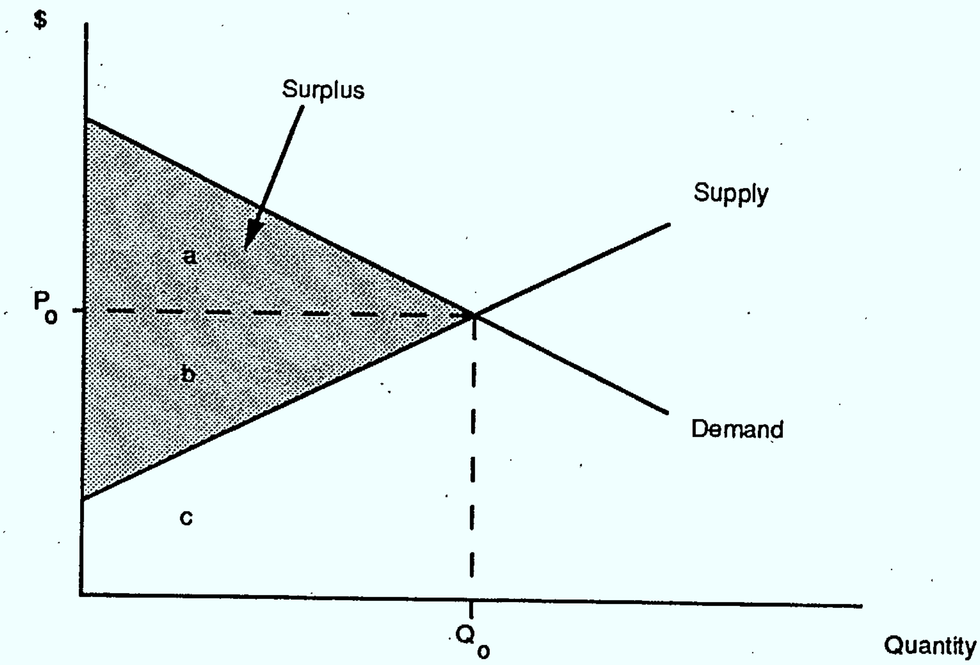
[7]i.e. increased rents to scarce factors of production.

[8]The conservative assumption was made that all revenue increases stemmed from new products. A similar revenue increase for existing products would have produced a larger estimate of benefits because it would include quality improvements in the volume of goods already being sold.

Figure 5.7

BENEFITS FROM IT SALES
FOR ONE PRODUCT



5.8 IT WILLINGNESS TO PAY MODULE

IT willingness to pay is driven by the net benefits provided by access to the network. However, there is a problem in attributing benefits to the appropriate year. The total benefit provided by the network in any given year will be equal to the present value of the increased profits over time created by testing products on the network. Thus, in any given year, willingness to pay is based on the net benefits of future years. How many years into the future should be counted towards the present year?

To estimate the present value of future profits in any one year, it was assumed that

- There was an average of four years lag between use of the test–bed and sales impact.
- That use of the network begins in year 1.
- That the life–cycle of IT products is 3 years (consistent with the 3 year depreciation cycle for advanced technology used in this study).

This means that the willingness to pay from any given year t is based on years increased sales projected for years (t+4), (t+5) and (t+6).

The willingness to pay calculation is based on the identity:

Revenue = (present value of future net benefits)*(Reduction Factor)

The reduction factor represents the joint impact of two considerations:

- The imperfection of capital markets. A firm investing in R&D is unlikely to pay any thing close to the full net present value of its proposed product. Because of the constrained access to capital for R&D, the effective cost of capital is much higher than indicated by capital markets.

- The inability to charge each firm the full value of its willingness to pay. This is the same problem in pricing outlined for R&D users. Since users will tend to be charged according to a standardized schedule rather than individually, they will always keep a substantial portion of their benefits as a "consumer's surplus". (See Figure 5.5)

It was judged that each firms willingness to pay for test–bed services would be at most one tenth the expected net present value of future profits from the product. This is further reduced by the second consideration to provide a mean estimated reduction factor of 5%. Because of the uncertainty associated with this estimate, a wide range of from 2.5% to 10% was chosen as the probability distribution.[9]

5.9 NETWORK COST MODULE

Relative to the great uncertainties surrounding benefits, network costs are relatively certain. For the ISTC network, the 5 year projection for the most extensive scenario, option 3, was used. The figures were reduced to remove the 5% assumed inflation, as the benefit/cost model calculates benefits in constant 1989 dollars.

For years beyond year 5, network costs were assumed to grow in proportion to the user–

[9] To be precise, an 80% confidence interval was assigned to the range 2.5% to 10%.

base, as measured in dollars of R&D expenditure represented by subscribers.

Note that these costs include a three year depreciation cycle for equipment. Every 3 years, equipment is assumed to be upgraded or replaced to provide the latest standards of network speed required for IT test–bed operations.[10]

The costs of the reference case were estimated similarly. Rough preliminary estimates were available placing the reference case costs at approximately $1.3 million per year for the first three years. In subsequent years this was also projected to grow in proportion to the user base.

5.10 NET BENEFITS MODULE

The outputs from the previous modules are combined to determine net benefits of the ISTC network and the reference case.

The two key summary statistics are the Net Present Value (NPV) and the Internal Rate of Return (IRR). The net present value is the difference between benefits and costs after future benefits and costs have been converted into their present day worth.[11] If the Net Present Value is positive, the project should be undertaken. The NPV is evaluated at a real rate of discount of 10%, the Treasury Board estimate of the long–run social cost of government borrowing. (e.g. A $1.10 benefit one year from now is worth $1.00 of cost today.)

The Internal Rate of Return specifies the rate of interest at which the project breaks even. If the NPV is positive, this will be greater than 10%. The IRR is useful for assessing the degree of risk associated with the project. The probability distribution provided for each output allows the assessment of the probability that a project's rate of return will fail to exceed the Treasury Board Guideline of 10%.

Other key summary values determined in this module are:

- Net benefits to R&D users only.
- Net benefits to IT test–bed users only.
- The likely break–even year of operation.

5.11 INCREMENTAL NET BENEFITS MODULE

The incremental net benefit module calculates the same summary outputs as the Net Benefits Module. The difference is that the values produced by the reference case are subtracted from the values produced for the ISTC network to produce an estimate of whether the incremental benefits of the ISTC network over the reference case exceed the incremental costs.

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[10] Thereby preserving the location on the "technology curve" of Chapter 1.

[11] A dollar in the future is worth less than a dollar today.

5.12 CAPTURING INTERVENTION RATIONALES

The test of government sponsorship is the break–even year estimated by the Net Benefits module. If the break–even is significantly in the future, then the free rider effect, discussed earlier, will prevent the private sector from offering a high speed research network on its own. Government sponsorship is called for, provided the present value of benefits exceeds costs.

Chapter 3, on potential rationales for government sponsorship, identified several potential considerations which would cause the break–even year to be delayed, even though the net benefits of proceeding immediately were positive.

This section reviews how consideration of those potential rationales has been included in the model.

- **Early Adoption**

  The pattern of early technology adoption and exponential growth through demonstration effect has been captured by the estimated growth in network subscribership over time (the uptake rates). It would have been unrealistic to assume that every private firm and institution which undertakes R&D would immediately subscribe to the network in year 1.

- **Pricing Externality**

  The constraints to raising revenue because of the inability to charge users individual prices (price discrimination) has been incorporated into the willingness to pay modules.

- **R&D Externality**

  The expectation that Canada underspends on R&D, and the conclusion that an additional dollar of R&D is worth more than one dollar, has been incorporated into the R&D Benefits Module. The value of R&D productivity gains is multiplied by the social benefits multiplier (SBMULT in the model).

  Imperfect capital markets for R&D funding have also been reflected in the reduction factors applied to willingness to pay for test–bed services by the IT industry.

- **Training Externality**

  The overestimation by R&D firms of training costs for maintaining staff skills has been incorporated into the R&D willingness to pay module by myopic expectations on the probability of having to train new hires.

- **Network Externality**

  The difficulty in obtaining subscribership in the early stages because of the small user base is dealt with in the assumption of aggressive network pricing and the exponential path taken over time by subscribership growth (the uptake rates).

- **Market Making in Information Services**

  The benefits of market making are found through the productivity impacts estimated for applications, particularly application group 5.

- **Industrial Benefits**

  These benefits have been incorporated in the IT benefit/cost module.

5.13 EMPLOYMENT BENEFITS

There are no benefits allowing for new job creation. Consideration of new job creation is not undertaken for these reasons:

- Treasury Board Benefit/Cost Guidelines recommend that job creation not be counted. Job creation is generally considered a matter for macro–economic policy. Counting them into project benefits leads to double counting benefits for government initiatives as a whole.

- Typical "economic impact" studies estimate jobs associated with new projects. Not all the jobs associated with a project are new job creations, but poor practice has lead to frequent misinterpretation.

- Treasury Board Benefit/Cost rules were written in 1976. Modern economic theory suggests that certain types of job creation should be counted as a project benefit if they lead to employment in particularly depressed sectors of the economy (structural unemployment).[12] However, the principal impacts of the high–speed network are in advanced technology areas. There is no reason to expect structural unemployment in these areas.

5.14 CONCLUSION

This chapter has described the principles and critical values of the benefit/cost estimation model. The appendices to this volume detail the equation structure and values selected for inputs. The next chapter reports results.

[12]More precisely, rectifying deficient demand caused unemployment is not a project benefit, but reducing structural unemployment might be counted under some circumstances.

6. RESULTS

This chapter provides answers to the three key questions posed in Chapter 1:

- Are the benefits of maintaining a network at high–end speeds greater than the costs?
- Are the incremental benefits of maintaining high–end speeds over low–end speeds greater than the incremental costs over lower end speeds?
- Are their significant public benefits which cannot be captured as revenue by a private sector operator? (i.e. is there a rationale for government sponsorship?)

The answers to these questions are presented after a brief discussion of the meaning of the key terms "net present value" and "internal rate of return". The chapter concludes with other estimates of interest generated by the model, and visual presentation of key results.

For an explanation of how to read the three types of output (probability distributions, decumulative distributions, and time series) please refer to the last section of Chapter 4 on Methodology.

6.1 KEY TERMS: NPV AND IRR

The two key summary statistics are the Net Present Value (NPV) and the Internal Rate of Return (IRR).

The Net Present Value tells us whether a project is worthwhile or not. If it is positive, the benefits are greater than the costs. NPV is the difference between benefits and costs after future benefits and costs have been converted into their present day worth. Calculation is based on the principle that a dollar tomorrow is worth less than a dollar today. In this case the NPV is evaluated at a real rate of discount of 10%, the Treasury Board estimate of the long–run social cost of government borrowing. (e.g. A $1.10 benefit one year from now is worth $1.00 of cost today.)

The Internal Rate of Return specifies the rate of interest at which the project breaks even. If the NPV is positive, this will be greater than 10%.

The IRR is useful for assessing the degree of risk associated with a project. It is possible that a project has a high average NPV, but that the risks associated with it are so great that their is a significant probability that the project will fail the to meet the Treasury Board guideline of a 10% rate of return. The probability distribution of the IRR allows a quantitative estimate of this risk.

6.2 THE 80% CONFIDENCE INTERVAL

In addition to the graphs, 80% confidence intervals will be reported for key values. They will consist of a low value, which has a 90% likelihood of being exceeded, and a high value, which has a 10% likelihood of being exceeded. This means that there is an 80% likelihood that the true value will fall between the low and the high value.

6.3 ALL DOLLARS ARE 1989

All dollars are reported as constant 1989 dollars. The effects of inflation have been removed.

When summing up the worth of a stream of costs or benefits over time, present value is used. As with net present value, this conversion is based on the principal that a dollar today is worth more than a dollar tomorrow. Using the guideline discount rate of 10%, for example, the present value of $1.10 next year is $1.00. $1.10 one year from now is equal in worth to $1.00 in the bank today.

6.4 THE BOTTOM LINE: IS A HIGH SPEED NETWORK ECONOMICALLY FEASIBLE?

Yes. Figure 6.1 shows that the present value of all future benefits is very likely to exceed the costs. The expected value in 1989 dollars is $2.23 billion, compared to mean expected network cost over the twenty years of $175 million. (See Figure 6.17 for net present value of network costs.)

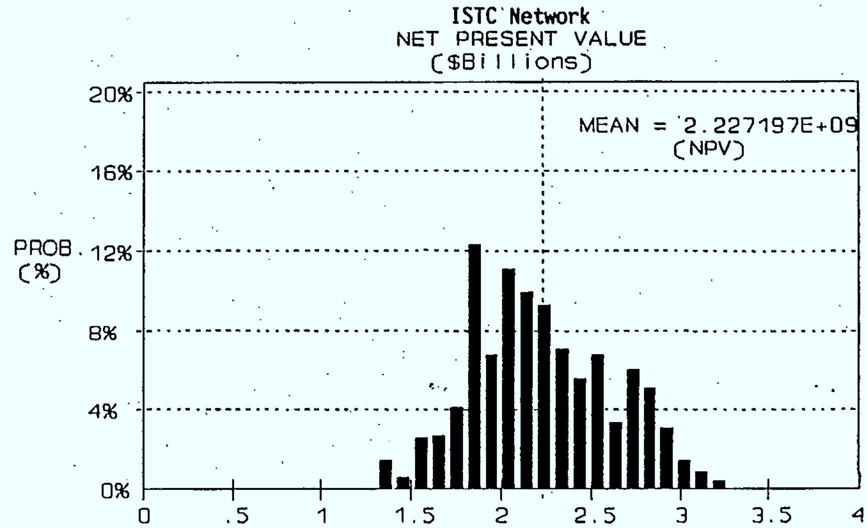
The decumulative distribution indicates an 80% confidence interval for NPV ranging from $1.74 billion to $2.79 billion.

This means that the Canadian economy is 90% certain to gain at least $1.74 billion over 20 years from the early introduction of a high-speed research network. The expected gain is $2.23 billion.

Figure 6.2 shows an average Internal Rate of Return of 61.1% with an 80% confidence interval of between 50.2% and 72.0%.

These are very strong rates of return, and indicate that, despite the broad uncertainty in individual key input values, the likelihood of the project failing the Treasury Board guideline of a 10% real return is negligible.

FIGURE 6.1


ISTC Network
NET PRESENT VALUE
($Billions)
MEAN = 2.227197E+09
(NPV)
PROB
(%)
20%
16%
12%
8%
4%
0%
0
.5
1
1.5
2
2.5
3
3.5
4

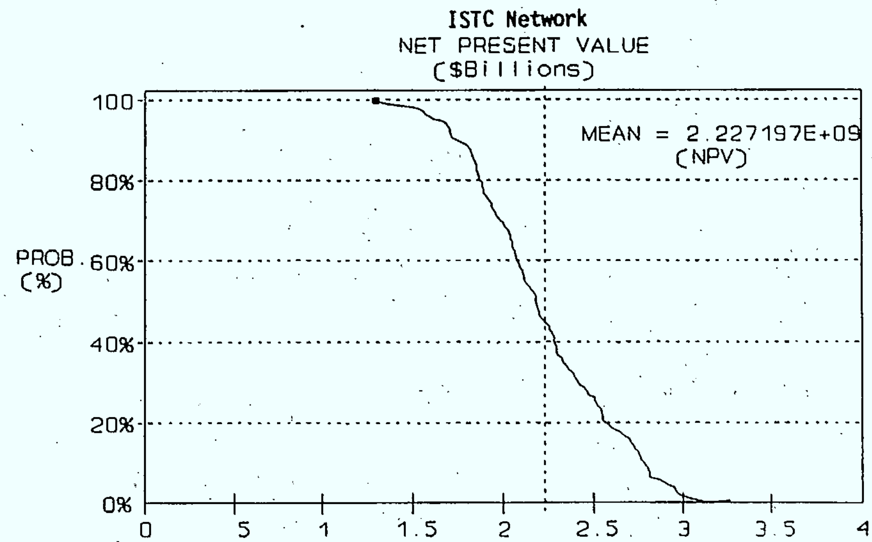
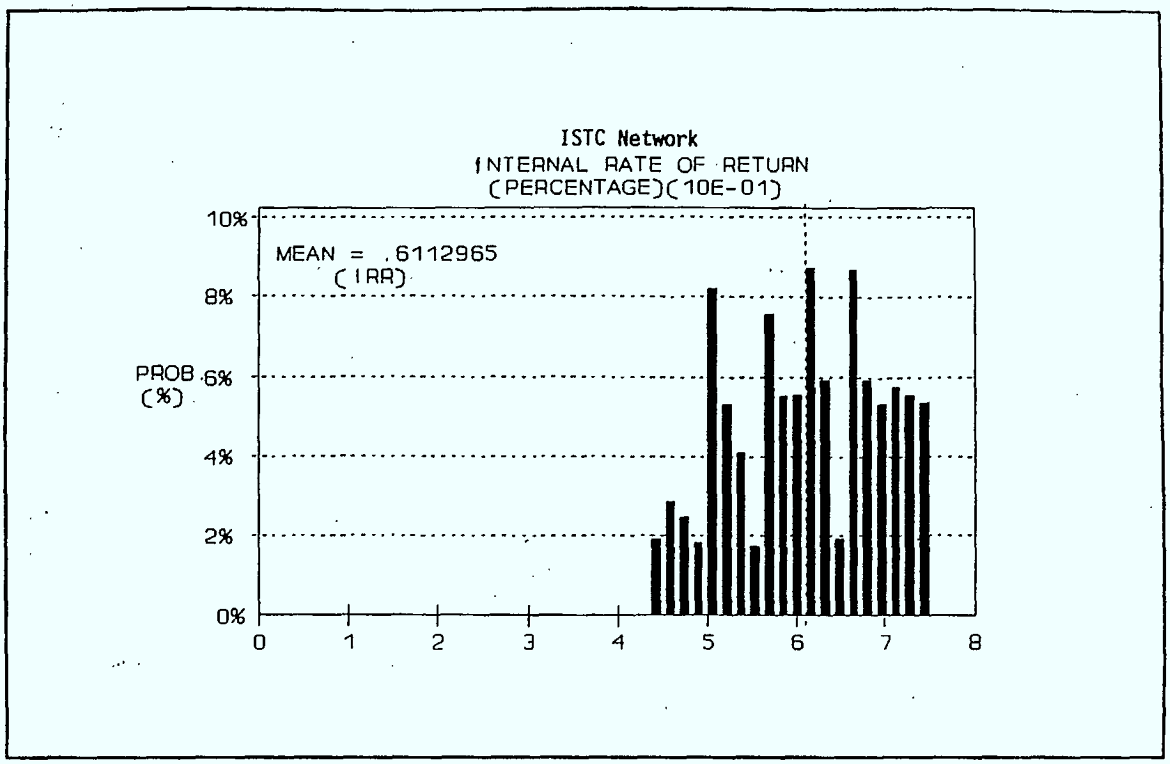
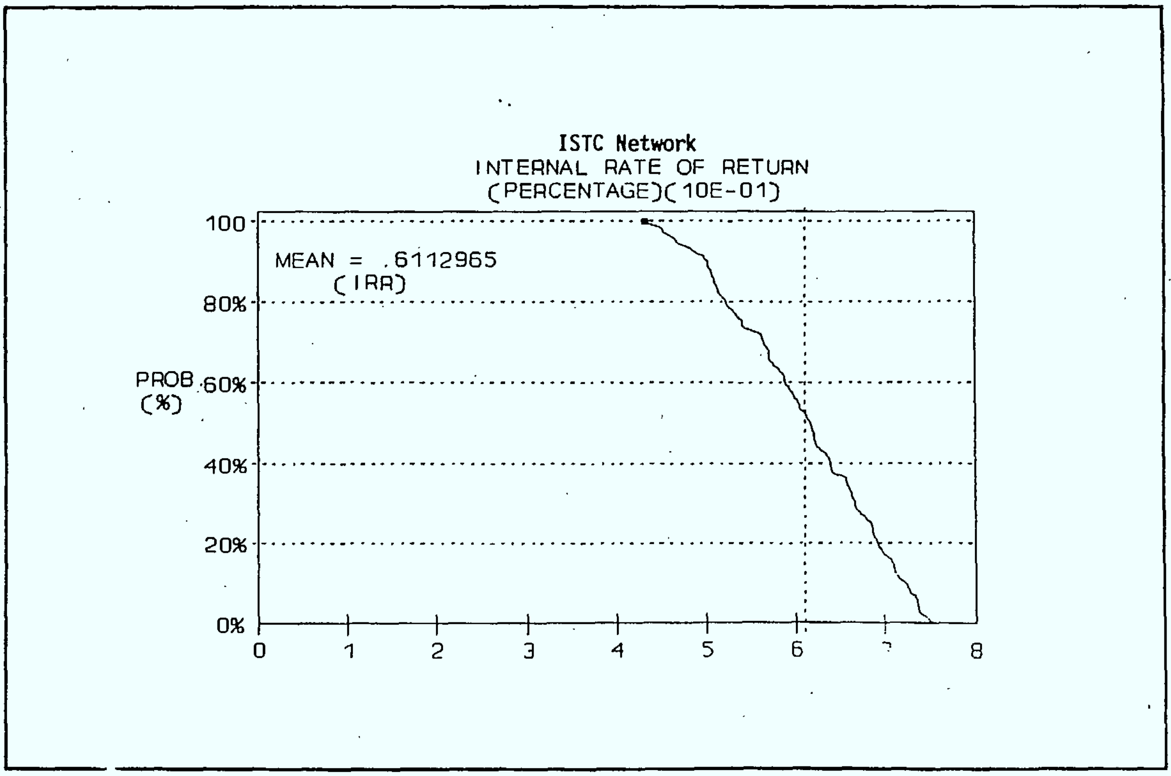

ISTC Network
NET PRESENT VALUE
($Billions)
MEAN = 2.227197E+09
(NPV)
PROB
(%)
100
80%
60%
40%
20%
0%
0
5
1
1.5
2
2.5
3
3.5
4

FIGURE 6.2


ISTC Network
INTERNAL RATE OF RETURN
(PERCENTAGE)(10E-01)
MEAN = .6112965
(IRR)
PROB
(%)
10%
8%
6%
4%
2%
0%
0
1
2
3
4
5
6
7
8


ISTC Network
INTERNAL RATE OF RETURN
(PERCENTAGE)(10E-01)
MEAN = .6112965
(IRR)
PROB
(%)
100
80%
60%
40%
20%
0%
0
1
2
3
4
5
6
8

6.5 IS THERE A RATIONALE FOR GOVERNMENT SPONSORSHIP?

Yes. The bottom graph of Figure 6.3 shows the excess of willingness to pay over costs. The zero line represents break–even. The mean expected break–even year, represented by the central line, is year 10 of operation. The 90% confidence interval lies between year 9 and year 13.

Year 9 is too far in the future for immediate private sector feasibility. Normal desirable break–even periods for the private sector fall within 5 years or less in North America. Given the special considerations of the free–rider problem (See chapter 5), the break–even horizon required by the private sector for this project would be shorter than 5 years.

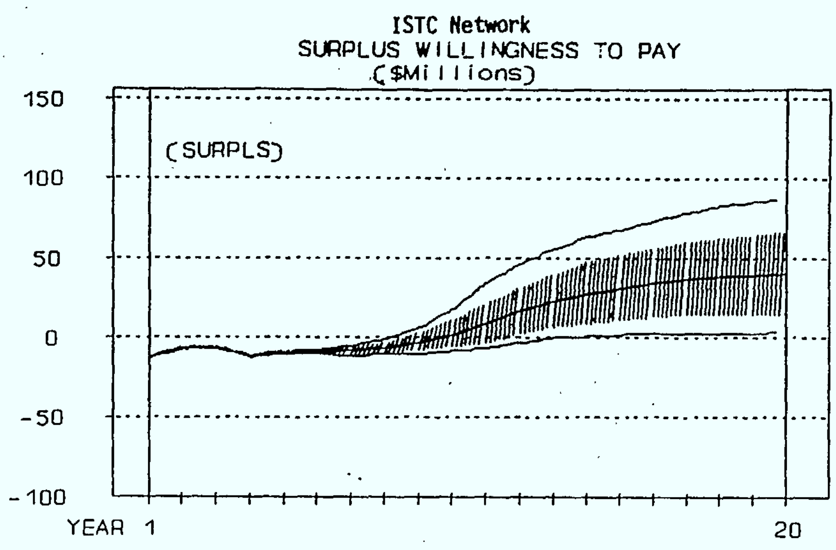
Therefore, although the long run benefits to the Canadian economy significantly outweigh the costs, the provision of a high speed network is unlikely without government sponsorship.

The short bump in surplus in years 2 and 3 is due to large costs in year 1 and 3 because of the 3 year capital renewal cycle.

Note the very wide range of uncertainty in surplus over later years. This arises from the great uncertainty on IT benefits, and IT willingness to pay. A significant amount of uncertainty was accounted for in the choice of demand and supply conditions because so little is known. However, despite the wide range of uncertainty, the 95% confidence interval indicated by the outside lines is still well above the zero line after year 13.

The top two graphs show willingness to pay by R&D and by IT test–bed users separately. Both begin slowly. The R&D willingness to pay line is held back by initial low private sector participation, and constraints on Government & Institutional willingness to pay. As noted in the previous chapter, it has been assumed that Governments & Institutions are not able to pay any more for the higher–speed ISTC network than for the lower–speed reference case, despite the significant additional productivity improvements. If government R&D users were able to pay an increased amount representative of the increased productivity gains, the break–even year could be advanced significantly.

FIGURE 6.3


ISTC Network
SURPLUS WILLINGNESS TO PAY
($Millions)
(SURPLS)
150
100
50
0
-50
-100
YEAR 1
20

6.6 IS THE INCREMENTAL BENEFIT OF THE ISTC NETWORK WORTH THE COST?

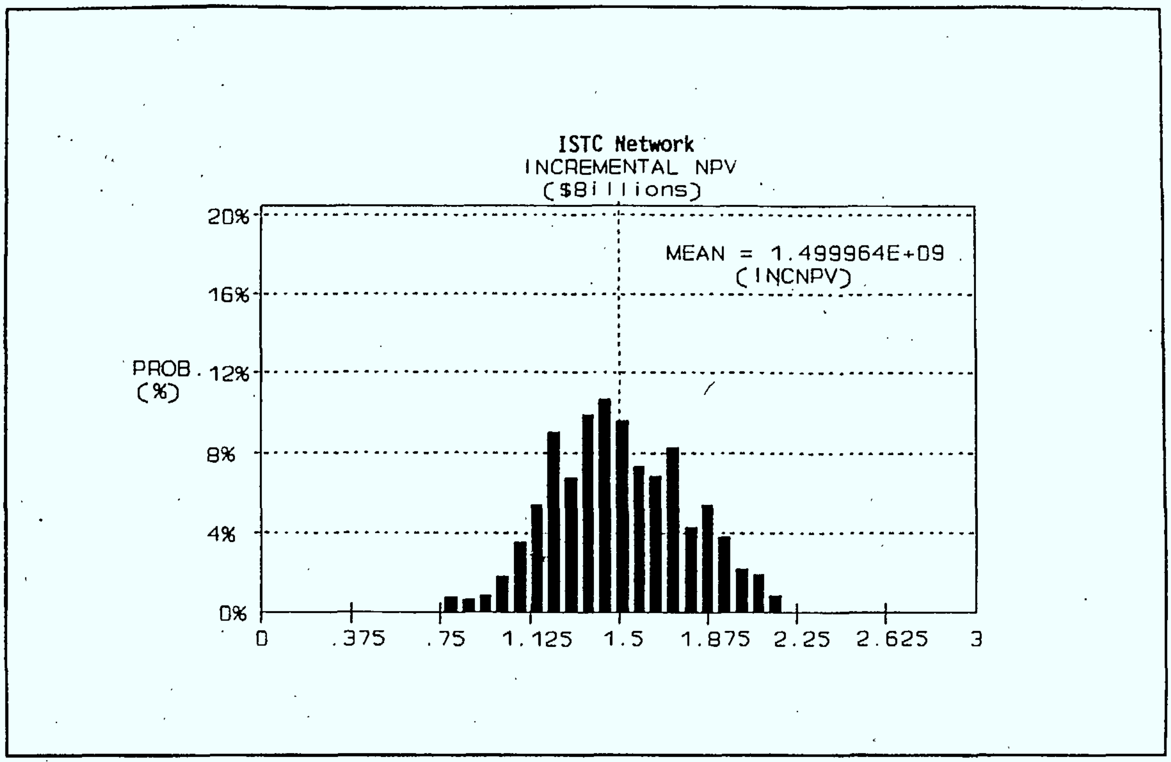
Yes. Figure 6.4 shows the incremental Net Present Value obtained by subtracting the benefits and costs of the low speed network reference case. The average NPV is $1.49 billion, with an 80% confidence interval from $1.14 billion to $1.90 billion.

This means that the Canadian economy is 90% certain to gain at least $1.14 billion from the ISTC network over a lower–speed option, and expected to gain $1.49 billion in 1989 dollars for the 20 year period.

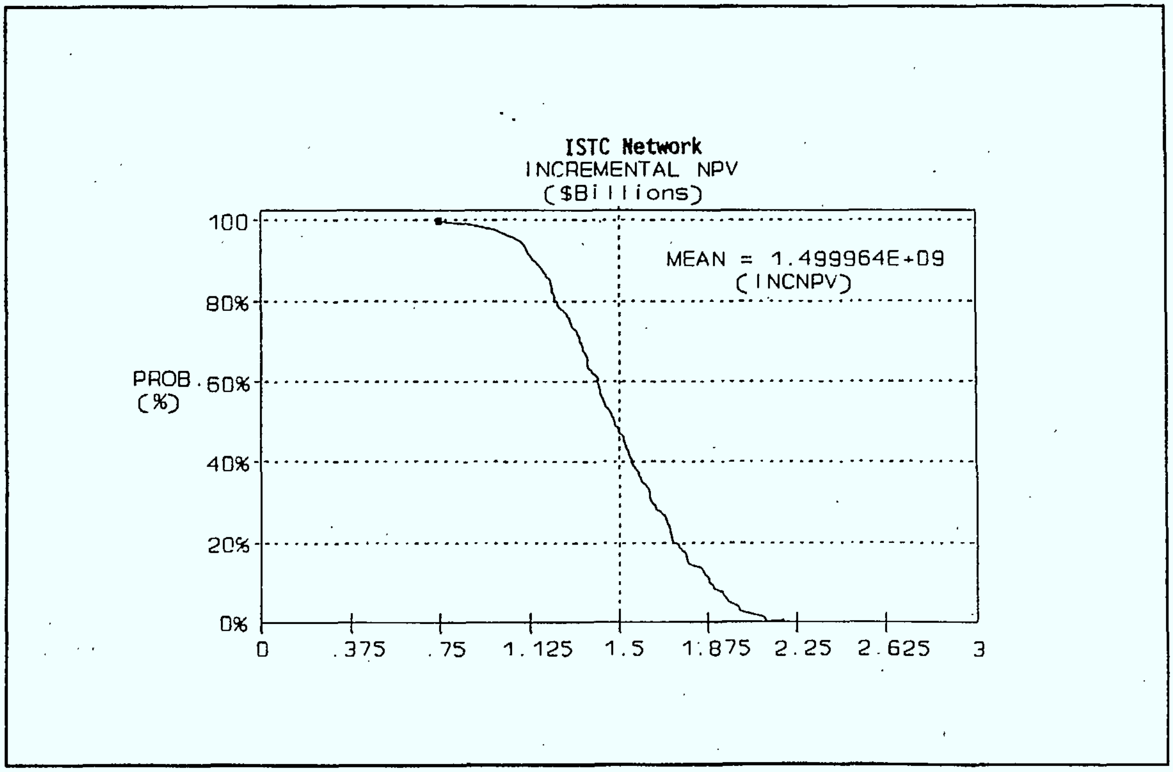
Complementing this assessment is Figure 6.5, showing that the Internal Rate of Return on the additional investment in the ISTC network is expected to be 53.2%. The 90% confidence interval is 44.8% to 61.5% rate of return. The likelihood of failing the Treasury Board guideline of a 10% rate of return is negligible.

Note that this positive finding for the ISTC network does not mean that the reference case does not also have a positive rate of return. In fact, the lower internal rate of return for the incremental benefit compared to the total benefit indicates a high rate of return on the reference case as well.

FIGURE 6.4



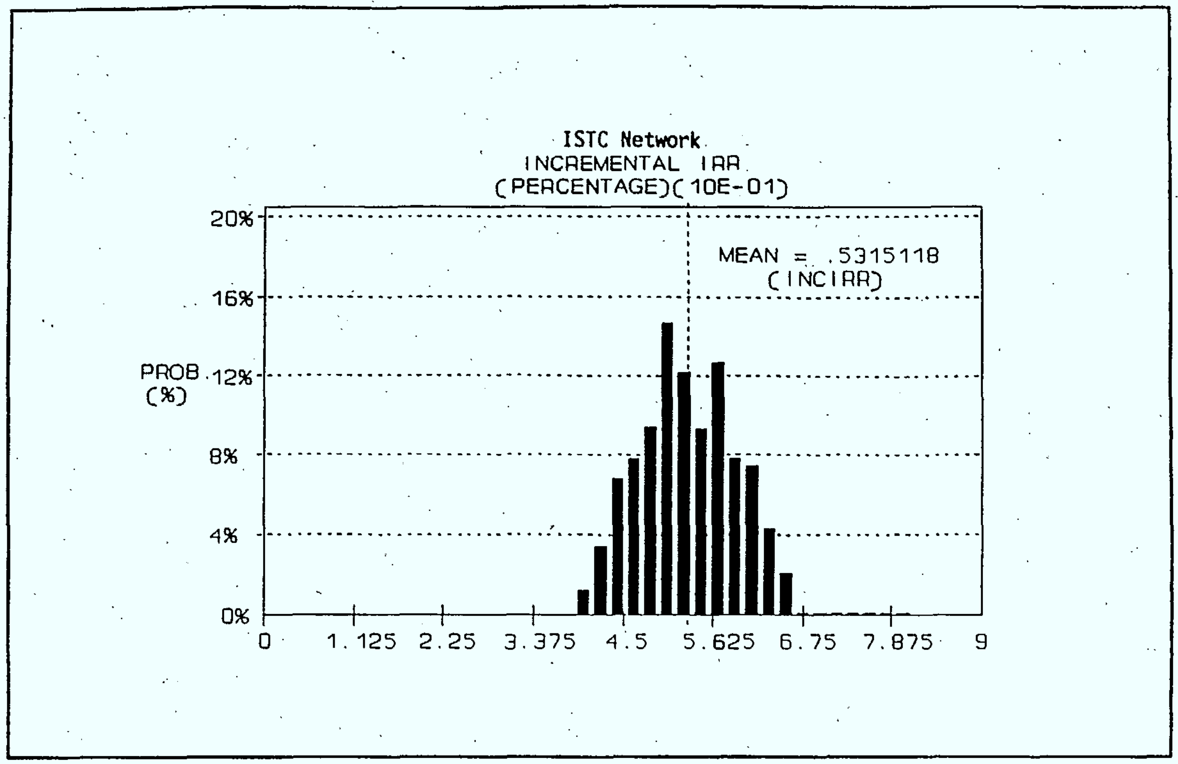
ISTC Network
INCREMENTAL NPV
($Billions)
MEAN = 1.499964E+09
(INCNPV)
PROB. (%)
20%
16%
12%
8%
4%
0%
0
.375
.75
1.125
1.5
1.875
2.25
2.625
3

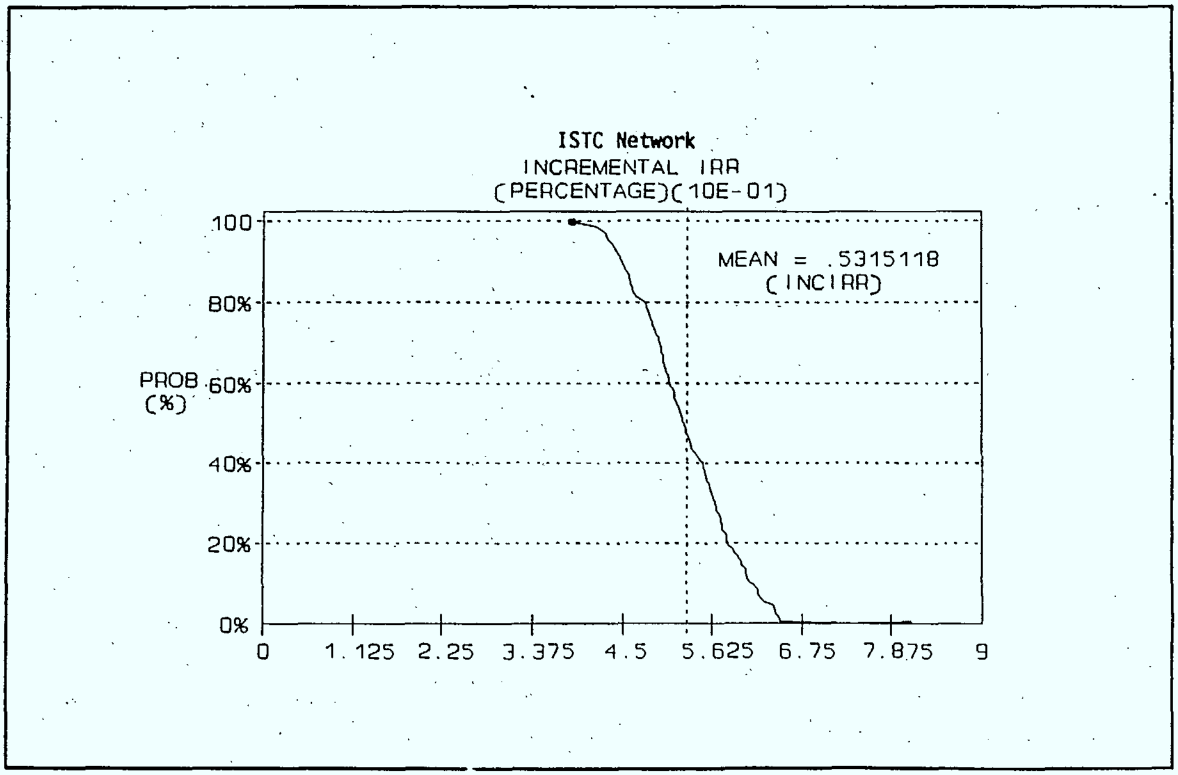


ISTC Network
INCREMENTAL NPV
($Billions)
MEAN = 1.499964E+09
(INCNPV)
PROB. (%)
100
80%
60%
40%
20%
0%
0
.375
.75
1.125
1.5
1.875
2.25
2.625
3

44

FIGURE 6.5


ISTC Network
INCREMENTAL IRR
(PERCENTAGE)(10E-01)
MEAN = .5315118
(INCIRR)
PROB
(%)
20%
16%
12%
8%
4%
0%
0
1.125
2.25
3.375
4.5
5.625
6.75
7.875
9


ISTC Network
INCREMENTAL IRR
(PERCENTAGE)(10E-01)
MEAN = .5315118
(INCIRR)
PROB
(%)
100
80%
60%
40%
20%
0%
0
1.125
2.25
3.375
4.5
5.625
6.75
7.875
9

6.7 WHAT IF WE EXCLUDE IT TEST-BED BENEFITS?

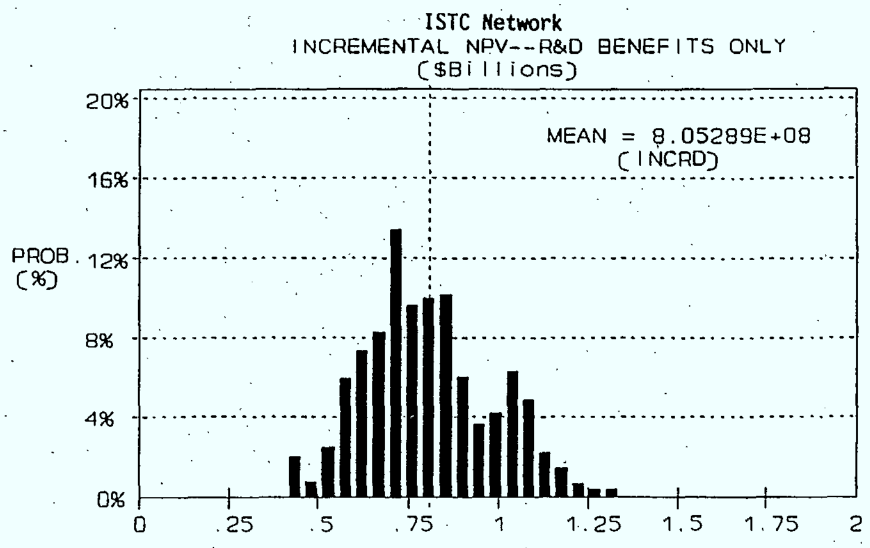
Figure 6.6 shows the Net Present Value of a high speed research network over a lower speed network if only R&D productivity benefits are counted. The project still has a very significant Net Present Value, at an expected value of $.81 billion and an 80% confidence interval from $.55 billion to $1.06 billion.

This means that the Canadian economy is 90% certain to gain better than $.55 billion from the early introduction of a network, even if use as an IT test-bed is excluded. However, the exclusion of the test-bed function is costly, bringing a reduction in the expected value of the network of $.7 billion.

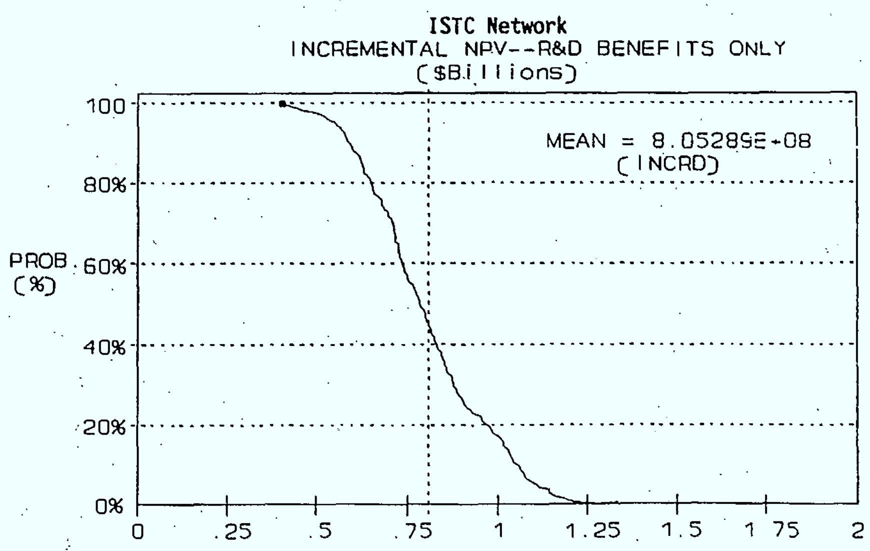
Figure 6.7 shows the incremental internal rate of return for the high speed network over a lower speed network if only R&D productivity benefits are counted. The expected rate of return is 39.8%, with an 80% confidence interval from 29.0% to 49.6%.

The probability of not meeting the Treasury Board guideline of 10% real rate of return is negligible.

FIGURE 6.6

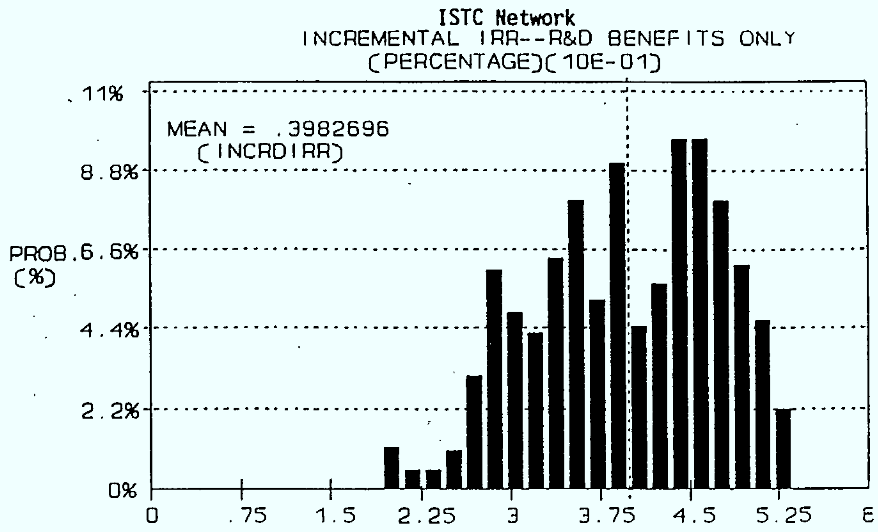


ISTC Network
INCREMENTAL NPV--R&D BENEFITS ONLY
($Billions)
MEAN = 8.05289E+08
(INCRD)
PROB (%)
20%
16%
12%
8%
4%
0%
0
.25
.5
.75
1
1.25
1.5
1.75
2

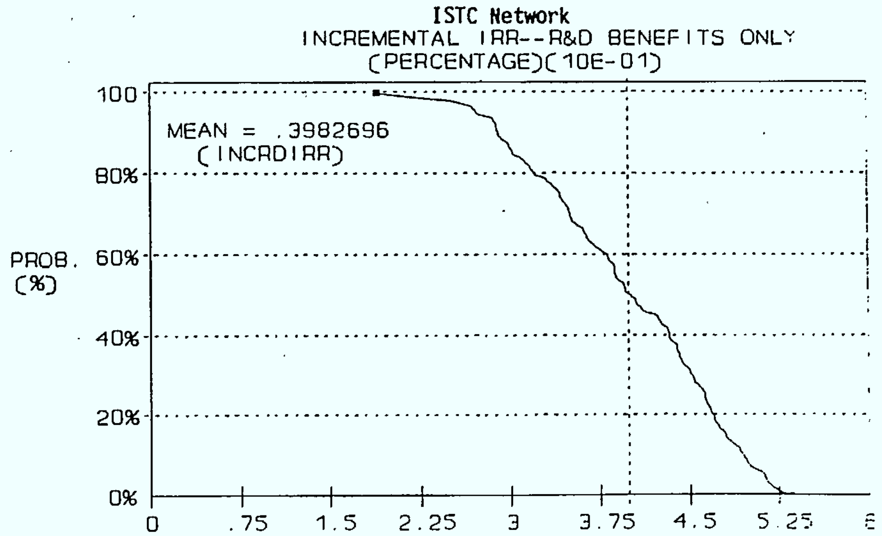


ISTC Network
INCREMENTAL NPV--R&D BENEFITS ONLY
($Billions)
MEAN = 8.05289E+08
(INCRD)
PROB (%)
100
80%
60%
40%
20%
0%
0
.25
.5
.75
1
1.25
1.5
1.75
2

FIGURE 6.7



ISTC Network
INCREMENTAL IRR--R&D BENEFITS ONLY
(PERCENTAGE)(10E-01)
MEAN = .3982696
(INCRDIRR)
PROB.
(%)
11%
8.8%
6.6%
4.4%
2.2%
0%
0
.75
1.5
2.25
3
3.75
4.5
5.25
6



ISTC Network
INCREMENTAL IRR--R&D BENEFITS ONLY
(PERCENTAGE)(10E-01)
MEAN = .3982696
(INCRDIRR)
PROB.
(%)
100
80%
60%
40%
20%
0%
0
.75
1.5
2.25
3
3.75
4.5
5.25
6

6.8 SOME UNDERLYING VALUES

Specific input ranges assigned to variables are given in Appendix C. However, the following commentary and graphics provide an overview of the principle characteristics of the model.

6.8.1 Comparing Network Participation

Tables 6.8 through 6.10 compare expected participation rates by the private sector, institutions, and governments between the ISTC Network, and the lower–speed network as currently proposed. Participation rates are measured as the percentage of that group's Canadian R&D expenditure accounted for by subscribers.

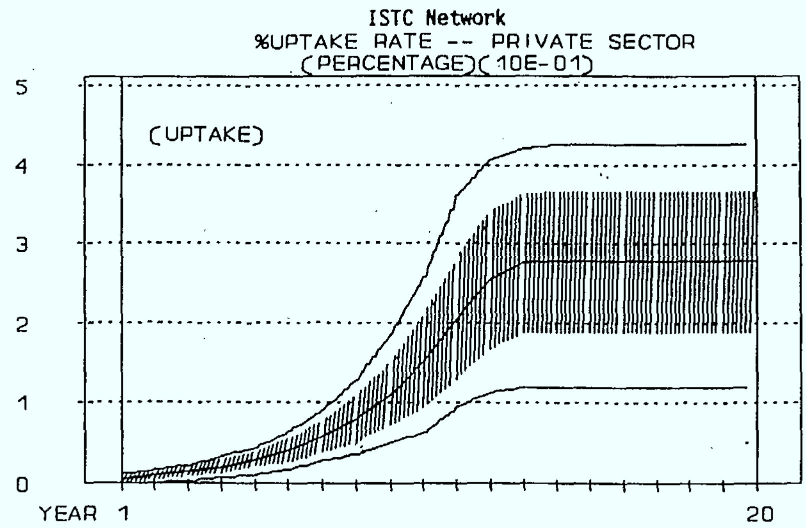
Care should be taken when comparing upper and lower graphs to note the different scales on the vertical axes.

Private sector participation is expected to be significantly higher for the ISTC network. Expected private sector participation rates are 28% for the ISTC network and 4.5% for the lower speed network. Private sector participation rates in Figure 6.8 show a wide band of uncertainty. In the 20th year, there is an 80% confidence interval from 15% to 40% for the ISTC network and 2% to 8% for the reference case. (Bottom graph is in smaller scale on vertical axis).

Government uptake rates are expected to be higher for the ISTC network, but not as significantly as with the private sector. Institutional uptake rates are also expected to be about the same in the two options. Figure 6.9 compares institutional uptake rates. Expected participation rates are roughly the same at 70% for ISTC and 70% for the lower speed option. Figure 6.10 compares government uptake rates. Expected participation is 60% for the ISTC network and 50% for the lower speed option.

Figure 6.11 shows the average participation rates over all three groups. Primarily because of higher private sector participation, expected participation is 45% for the ISTC network and 29% for the lower speed option currently represented by the reference case.

FIGURE 6.8


ISTC Network
%UPTAKE RATE -- PRIVATE SECTOR
(PERCENTAGE)(10E-01)
(UPTAKE)
0
1
2
3
4
5
YEAR 1
20

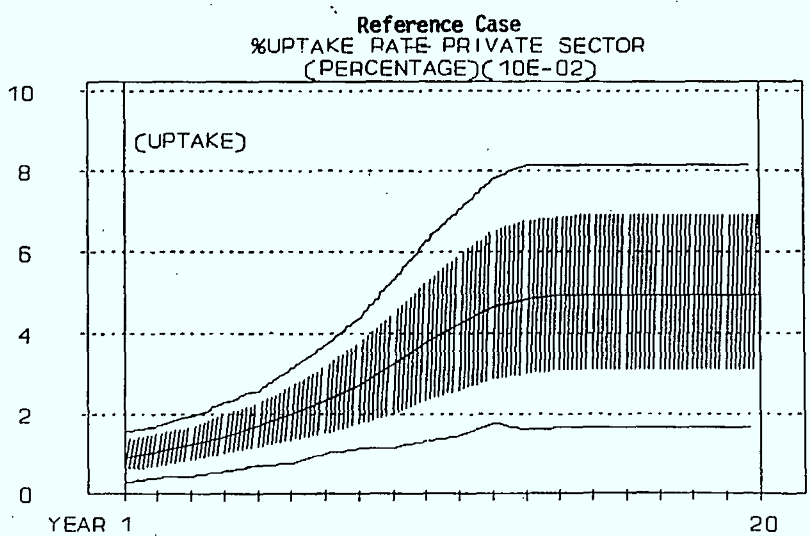
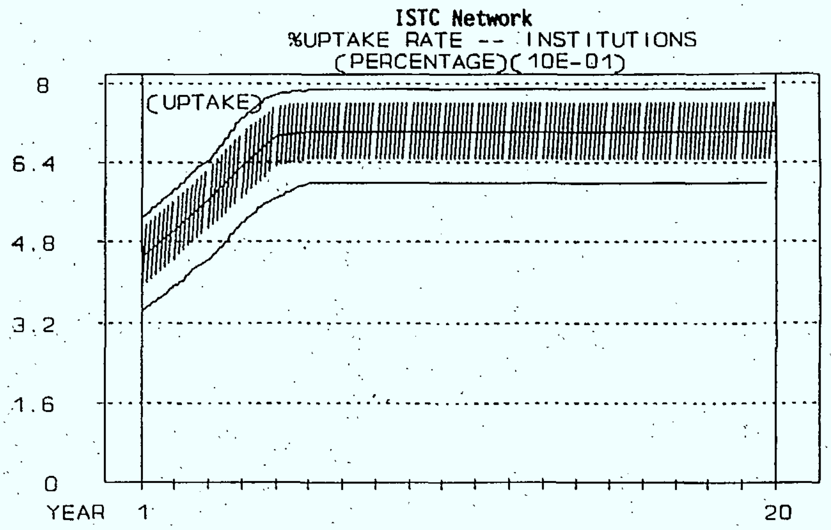

Reference Case
%UPTAKE RATE PRIVATE SECTOR
(PERCENTAGE)(10E-02)
(UPTAKE)
0
2
4
6
8
10
YEAR 1
20

FIGURE 6.9


ISTC Network
%UPTAKE RATE -- INSTITUTIONS
(PERCENTAGE)(10E-01)
8
6.4
4.8
3.2
1.6
0
(UPTAKE)
YEAR 1
20

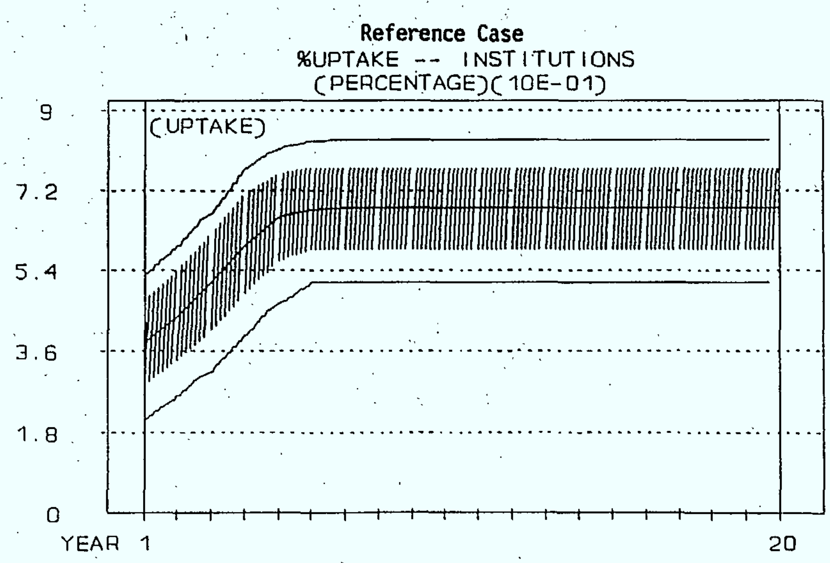
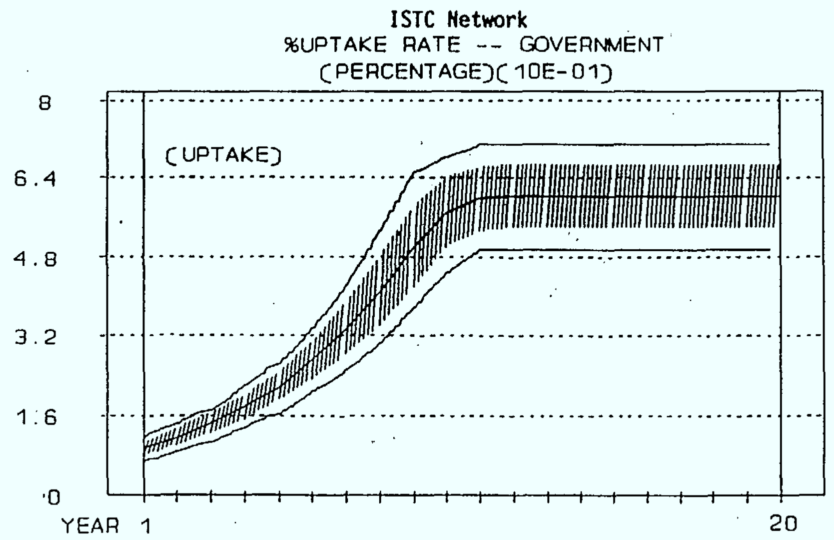

Reference Case
%UPTAKE -- INSTITUTIONS
(PERCENTAGE)(10E-01)
9
7.2
5.4
3.6
1.8
0
(UPTAKE)
YEAR 1
20

FIGURE 6.10


ISTC Network
%UPTAKE RATE -- GOVERNMENT
(PERCENTAGE)(10E-01)
(UPTAKE)
8
6.4
4.8
3.2
1.6
0
YEAR 1
20

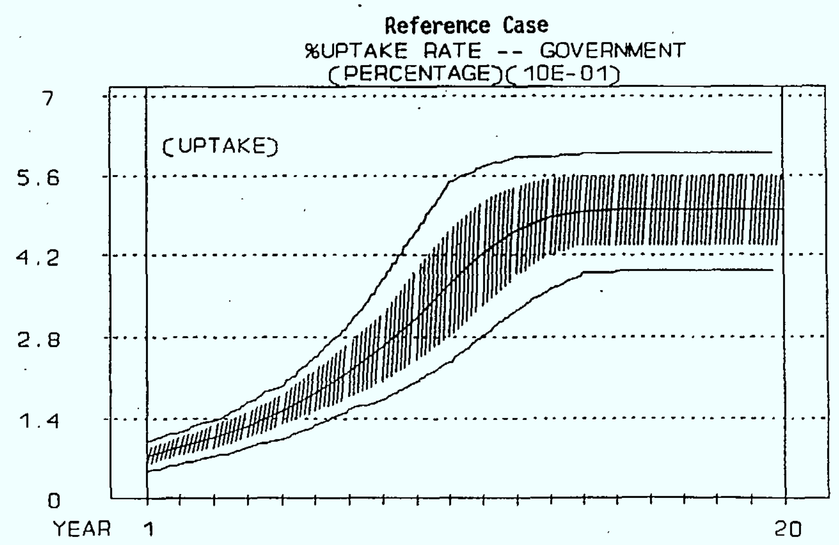
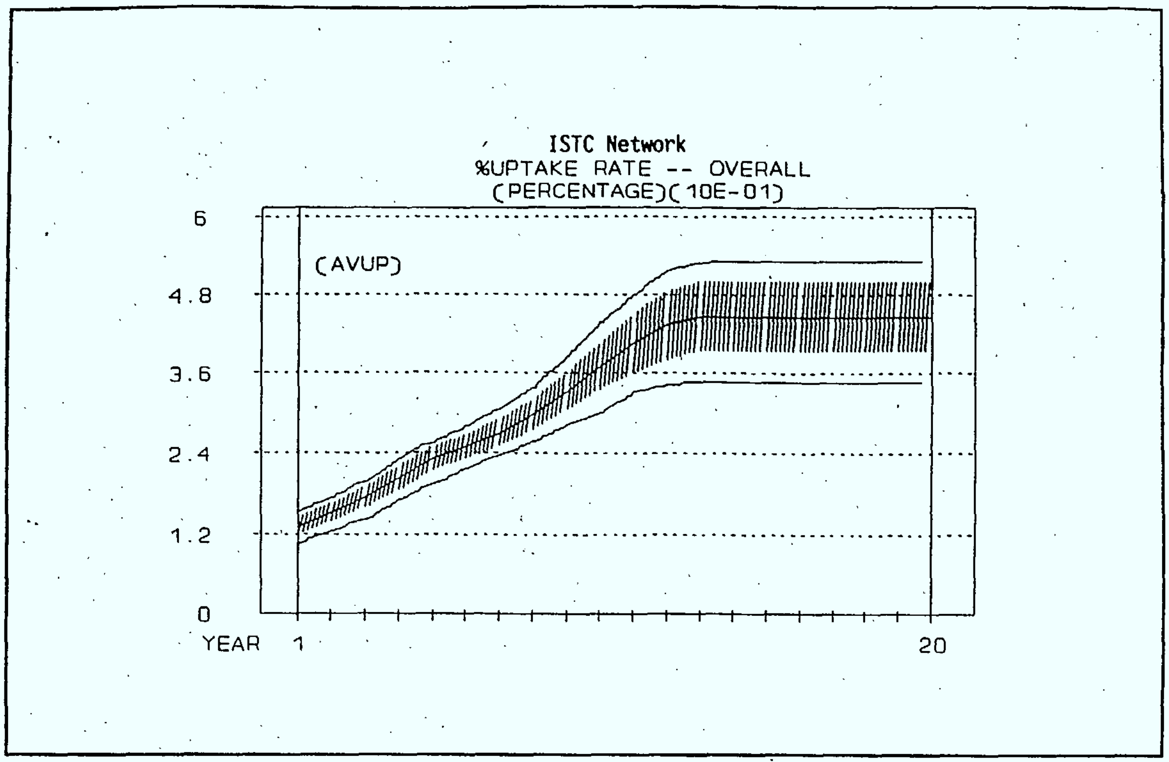
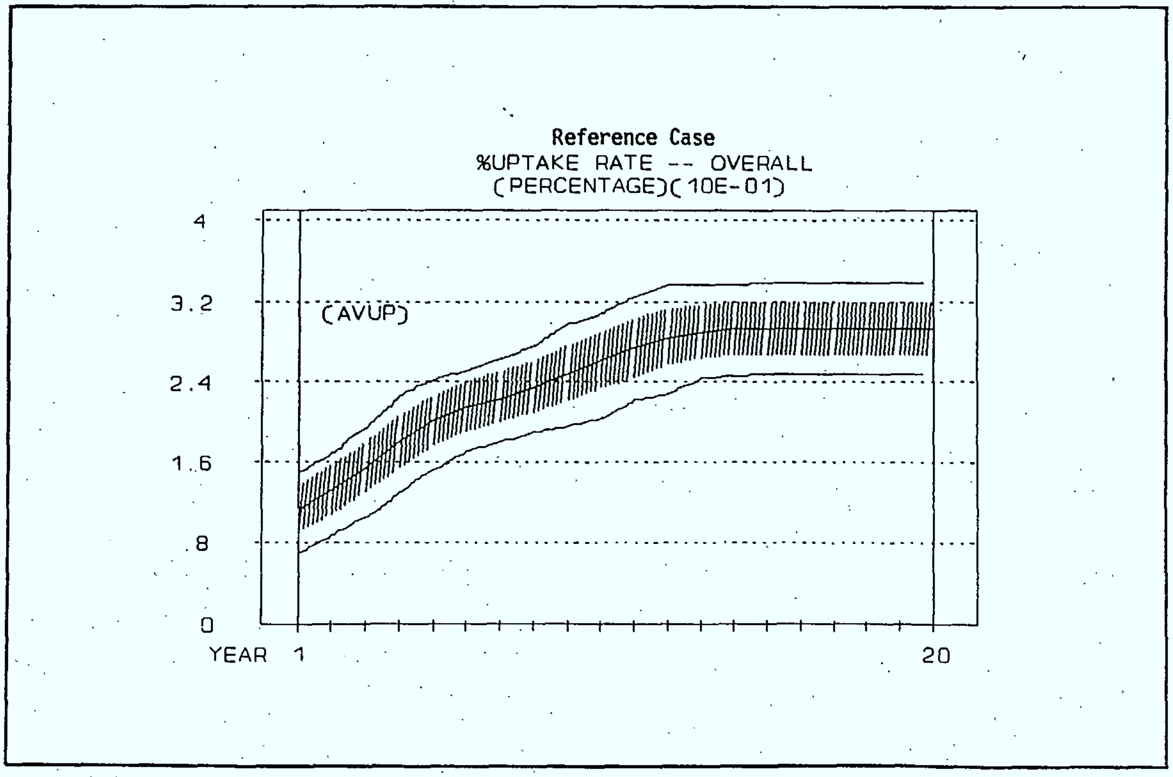

Reference Case
%UPTAKE RATE -- GOVERNMENT
(PERCENTAGE)(10E-01)
(UPTAKE)
7
5.6
4.2
2.8
1.4
0
YEAR 1
20

FIGURE 6.11


ISTC Network
%UPTAKE RATE -- OVERALL
(PERCENTAGE)(10E-01)
(AVUP)
6
4.8
3.6
2.4
1.2
0
YEAR 1
20

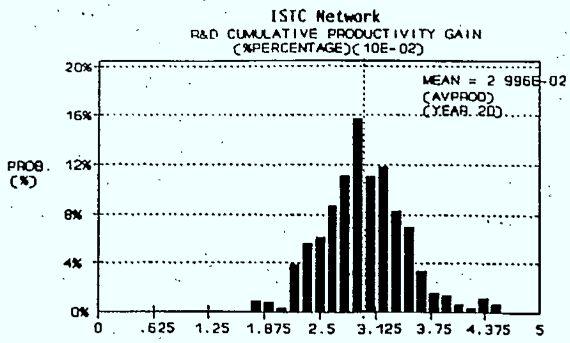

Reference Case
%UPTAKE RATE -- OVERALL
(PERCENTAGE)(10E-01)
(AVUP)
4
3.2
2.4
1.6
.8
0
YEAR 1
20

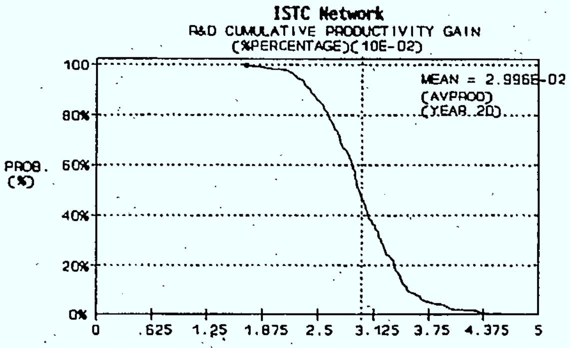
6.8.2 Productivity Gains

Figure 6.12 shows the expected productivity impact on R&D from all applications on the ISTC network. The top graph shows how productivity impact grows over 20 years, while the bottom two graphs illustrate year 20. The mature productivity impact of the ISTC network is expected to be 2.99% with an 80% confidence interval from 2.42% to 3.52%.

By comparison, Figure 6.13 shows that the lower speed network has an expected mature productivity impact of 1.95% by year 20, with an 80% confidence interval from 1.56% to 2.33%. The difference in average productivity between the two comes from a different make up of the subscriber base, since mature productivity impacts of individual applications are presumed to be the same.

FIGURE 6.12


ISTC Network
R&D CUMULATIVE PRODUCTIVITY GAIN
(%PERCENTAGE)(10E-02)
MEAN = 2 996E-02
(AVPROD)
(YEAR 20)
PROB. (%)
20%
16%
12%
8%
4%
0%
0
.625
1.25
1.875
2.5
3.125
3.75
4.375
5


ISTC Network
R&D CUMULATIVE PRODUCTIVITY GAIN
(%PERCENTAGE)(10E-02)
MEAN = 2.996E-02
(AVPROD)
(YEAR 20)
PROB. (%)
100
80%
60%
40%
20%
0%
0
.625
1.25
1.875
2.5
3.125
3.75
4.375
5

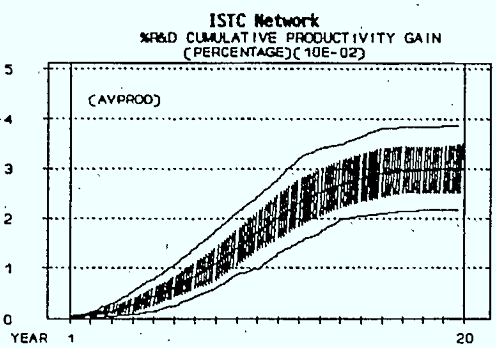
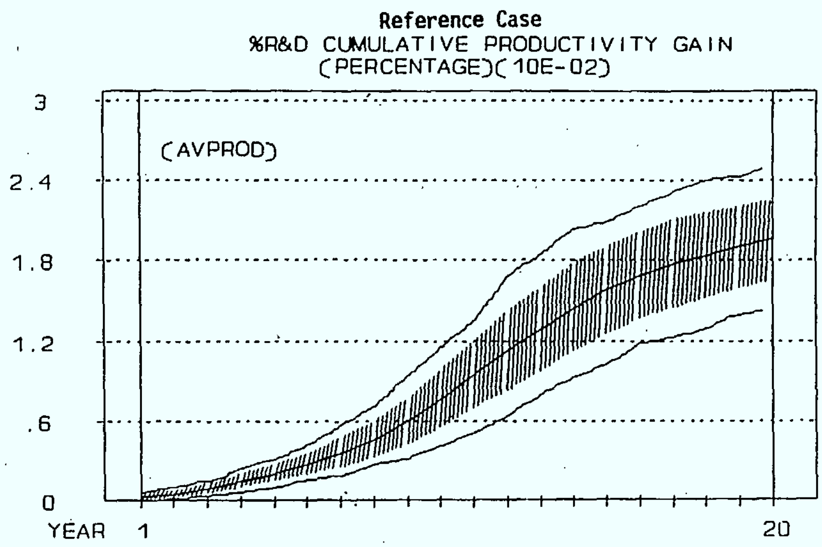

ISTC Network
%R&D CUMULATIVE PRODUCTIVITY GAIN
(PERCENTAGE)(10E-02)
(AVPROD)
5
4
3
2
1
0
YEAR
1
20

FIGURE 6.13


Reference Case
%R&D CUMULATIVE PRODUCTIVITY GAIN
(PERCENTAGE)(10E-02)
3
2.4
1.8
1.2
.6
0
(AVPROD)
YEAR 1
20

6.8.3 IT Sales Impact

The impact of test–bed availability on sales by the Canadian Information Technology industry is expected to significant, but delayed. The delay is caused by the natural lead time between product development and sales, the need for test–bed use to mature over time, and the need for the IT test–bed user base to grow.

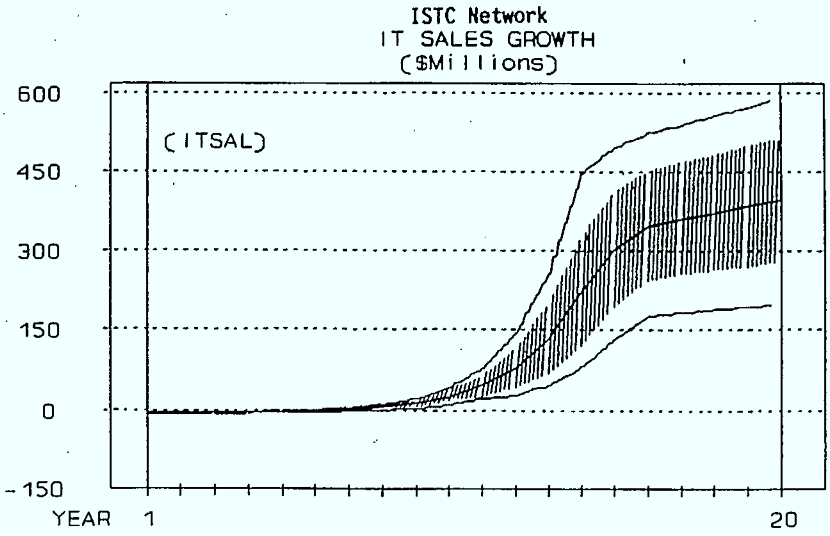
Current IT sales are $23.5 billion (1989).[13] Without the network, sales are assumed to grow in proportion to the Gross Domestic Product.

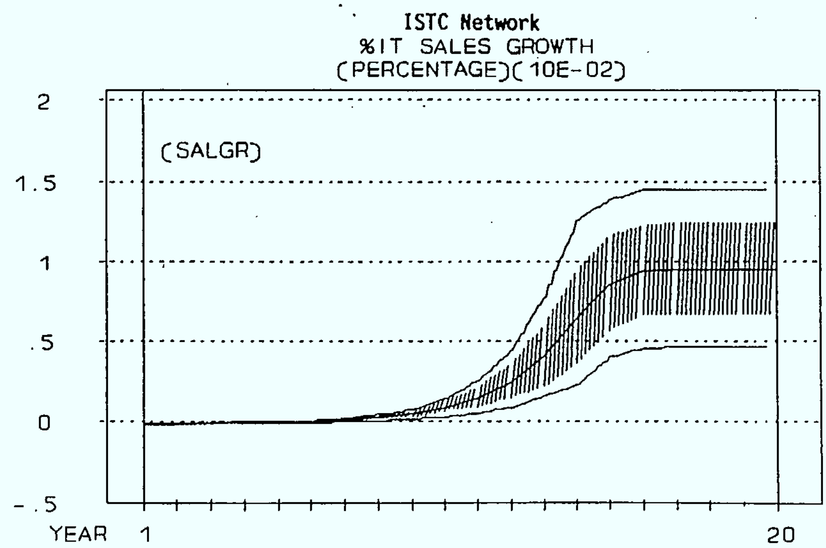
Figure 6.14 illustrates sales impact by the network. IT sales impact begins in year 5 and grows exponentially to its maturity by year 17. Expected mature impact on sales is 0.96% with an 80% confidence interval from 0.58% to 1.34%.

This means that there is a 90% likelihood that the impact on Canadian IT sales will exceed 0.58% of the current sales volume. In dollar terms, the expected increase at maturity (allowing for GDP growth as well) is $395 million, with an 80% confidence interval from $238 million to $551 million.

[13] Derived from CANTECH database. See Chapter 2.

FIGURE 6.14


ISTC Network
IT SALES GROWTH
($Millions)
(ITSAL)
600
450
300
150
0
-150
YEAR
1
20


ISTC Network
%IT SALES GROWTH
(PERCENTAGE)(10E-02)
(SALGR)
2
1.5
1
.5
0
-.5
YEAR
1
20

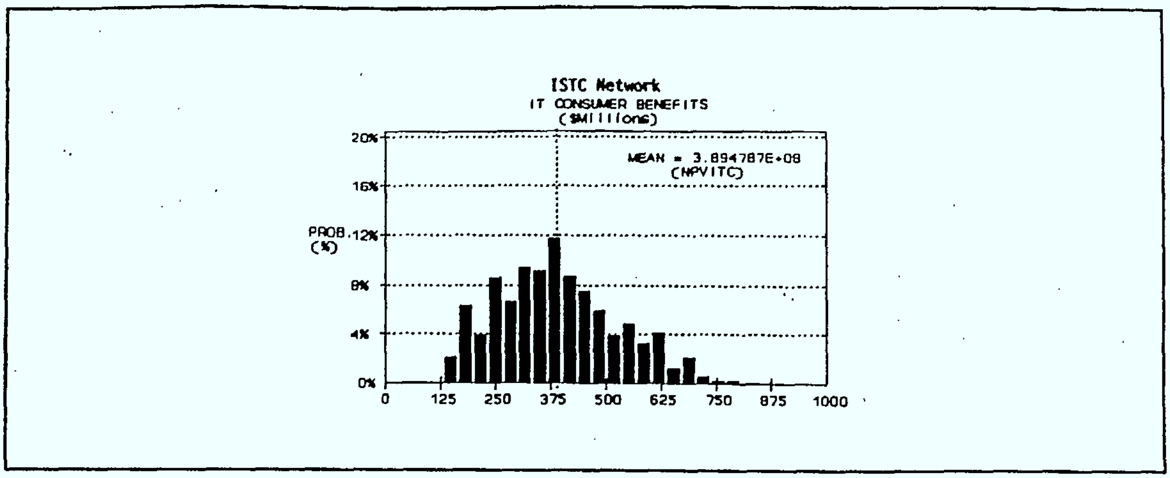
6.8.4 IT Benefits

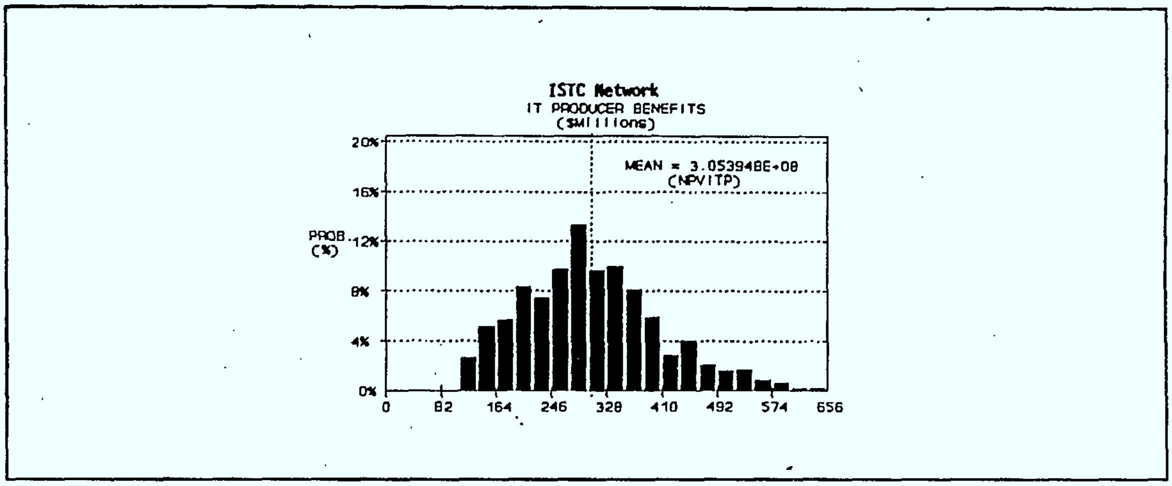
Figure 6.15 shows a breakdown of benefits to the IT industry. Total benefits over the twenty years are an expected present value of $694.9 million 1989 dollars. The 80% confidence interval is $403.1 to $997.2 million.

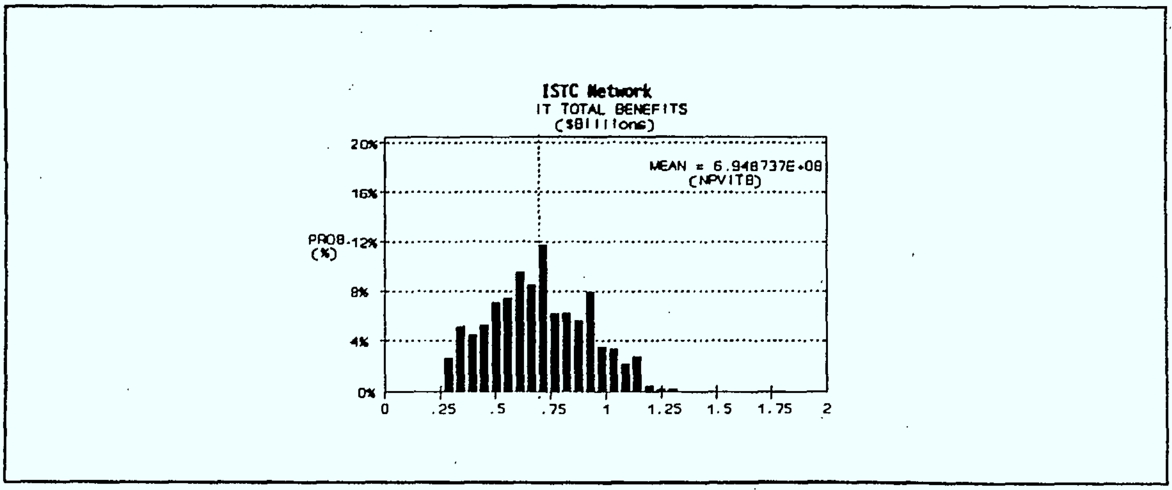
Consumer benefits are an expected present value of $389.5 million, with an 80% confidence interval of $226.2 to $586.3 million.

Producer benefits are an expected present value of $305.4 million, with an 80% confidence interval of $171.7 to $448.7.

FIGURE 6.15


ISTC Network
IT CONSUMER BENEFITS
($Millions)
MEAN = 3.894787E+08
(NPVITC)
PROB. (%)
20%
16%
12%
8%
4%
0%
0
125
250
375
500
625
750
875
1000


ISTC Network
IT PRODUCER BENEFITS
($Millions)
MEAN = 3.053948E+08
(NPVITP)
PROB. (%)
20%
16%
12%
8%
4%
0%
0
82
164
246
328
410
492
574
656


ISTC Network
IT TOTAL BENEFITS
($Billions)
MEAN = 6.948737E+08
(NPVITB)
PROB. (%)
20%
16%
12%
8%
4%
0%
0
.25
.5
.75
1
1.25
1.5
1.75
2

6.8.5 Comparing Network Costs

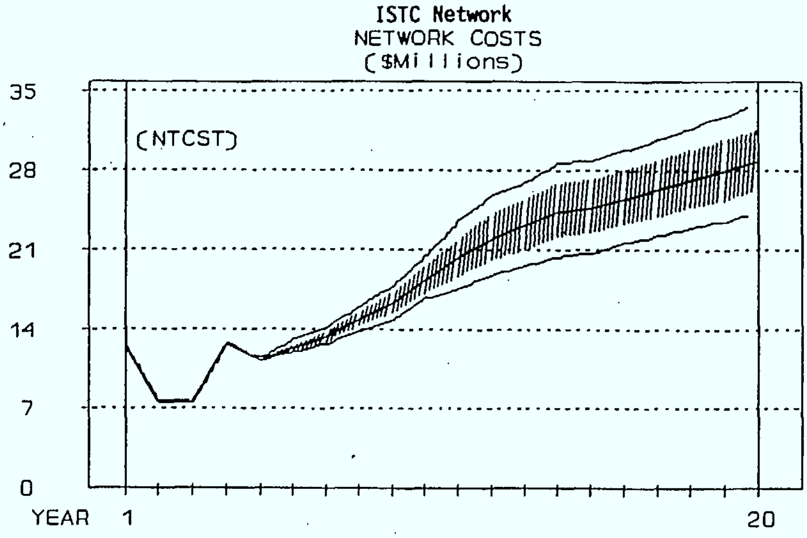
Figure 6.16 shows the time series for network costs for the ISTC network and the reference case. Costs are known with reasonably certainty for the first 5 years of the ISTC network. Current estimates for the reference case are based on expectations for CAnet in the first five years.

As covered in Chapter 5, network costs beyond these short term planning horizons are assumed to grow in proportion to the subscriber base. The uncertainty in the subscriber base generates the band of uncertainty in subsequent years.

Figure 6.17 shows the present value of costs over the evaluation period. For the ISTC network, the expected present value of costs is $175.1 million, with an 80% confidence interval of $162.8 million to $189.0 million.

The reference case is significantly less expensive at an expected present value of $18.0 million, with an 80% confidence interval of $17.2 to $19.2 million.

FIGURE 6.16


ISTC Network
NETWORK COSTS
($Millions)
(NTCST)
35
28
21
14
7
0
YEAR
1
20

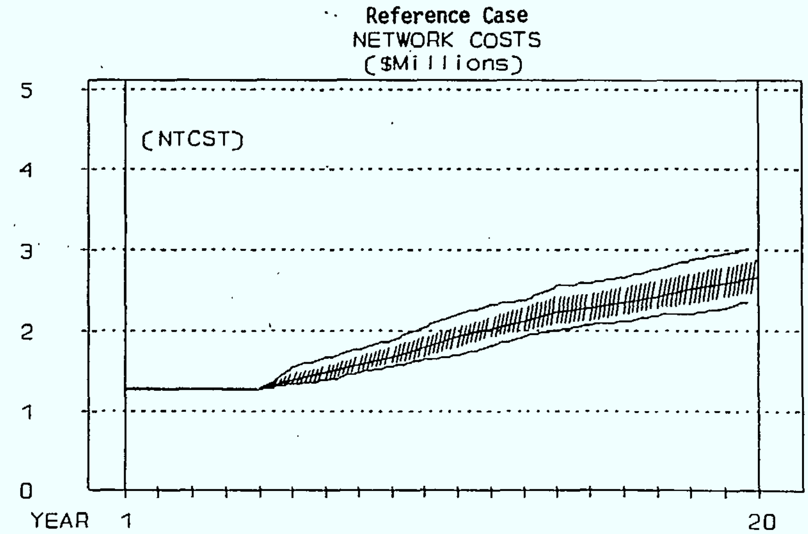
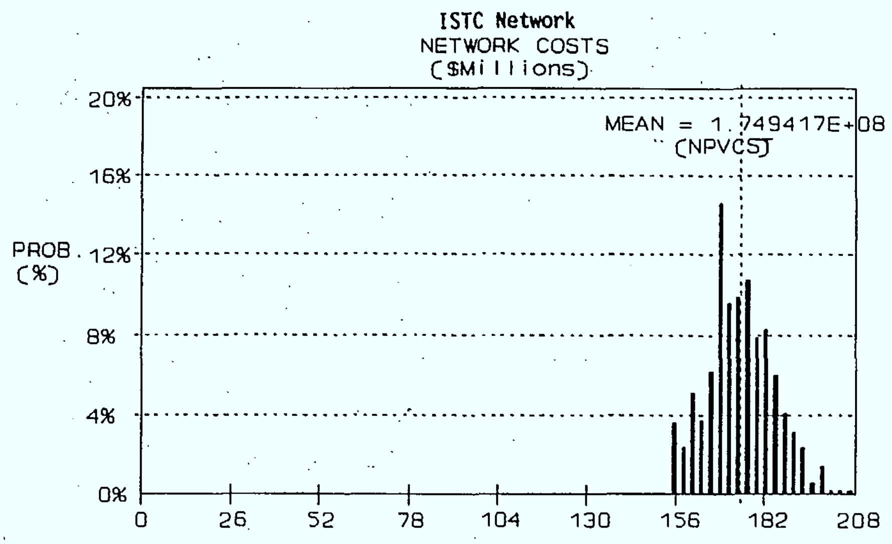
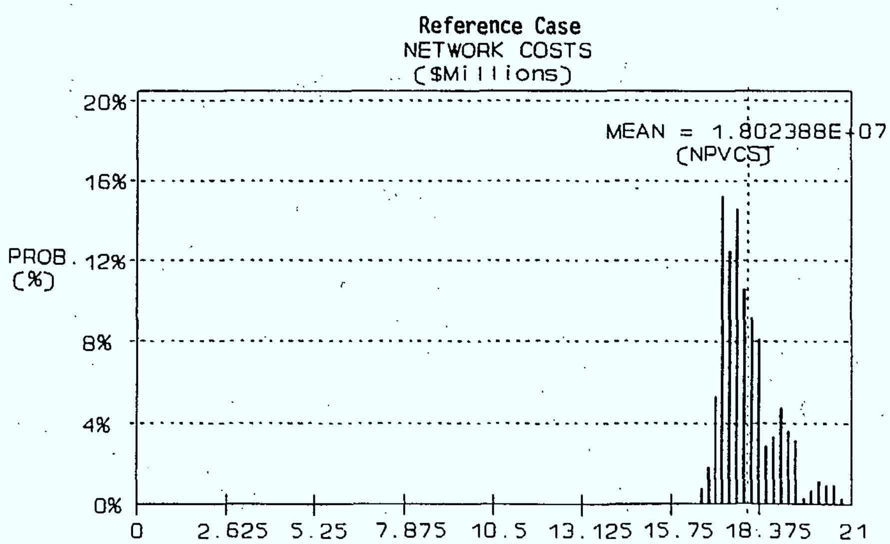

Reference Case
NETWORK COSTS
($Millions)
(NTCST)
5
4
3
2
1
0
YEAR
1
20

FIGURE 6.17


ISTC Network
NETWORK COSTS
($Millions)
MEAN = 1.749417E+08
(NPVCS)
PROB (%)
20%
16%
12%
8%
4%
0%
0
26
52
78
104
130
156
182
208


Reference Case
NETWORK COSTS
($Millions)
MEAN = 1.802388E+07
(NPVCS)
PROB (%)
20%
16%
12%
8%
4%
0%
0
2.625
5.25
7.875
10.5
13.125
15.75
18.375
21

7. CONCLUSION

The economic feasibility of the proposed high speed research network was assessed using RAP, a risk sensitive process, because of significant uncertainties concerning many key benefit determining factors.

Despite the uncertainty with individual values, the network shows a very robust positive return. This indicates that, under any combination of likely circumstances, a high speed research communications network is an excellent investment for Canada.

With regard to the three crucial question posed in Chapter 1:

1. **Yes, the benefits of the high speed network proposed by ISTC may be expected to significantly exceed costs.**

   The network will allow Canadian R&D workers to share facilities, to collaborate, to access new services, and to overcome the isolation of the small Canadian R&D community. The impact of the increased cooperation and specialization permitted by the network is comparable, in both size and effect, to the historical impact of transportation investments. The average productivity gain at maturity is 90% certain to exceed 2.4%, a significant gain on an R&D expenditure of $8.3 billion in 1989. The expected productivity gain is 3.0%.

   In addition, the benefits of providing a test–bed facility for Canada's Information Technology industry is also sufficient, on its own, to warrant the investment. The provision of a test–bed offers significant market opportunities to Canadian industry, resulting in an increase in sales, at maturity, of from $238 to $551 million annually.

   The project is 90% certain to return a net gain of $1.74 billion in present value terms ($1989), approximately 10 times its cost over the same 20 year evaluation period. The expected benefit is $2.23 billion.

   The real rate of return is 90% certain to exceed 50.2%, and is expected to be 61.1%. The likelihood of failing the Treasury Board's 10% rate of return guideline is negligible.

2. **Yes, the additional benefit of choosing the high speed network proposed by ISTC over lower speed options is expected to significantly exceed the additional cost.**

   A lower speed network also has a high rate of return, and is significantly cheaper. However, a lower speed network sacrifices all the benefits of a test–bed for the Canadian Information Technology industry, and it significantly postpones productivity gains for the R&D sector.

   An IT test–bed requires state–of–art network speed to test new products and services. The gain sacrificed from adopting a low speed network and losing the IT test–bed function is 90% certain to exceed a present value of $403 million, and is expected to be $694.9 million.

The postponement of productivity gains is also a significant loss to the economy. A lower-speed network restricts the applications that can be offered and provides poorer service for those seeking to seriously collaborate or share facilities. While the cost of higher speeds will eventually become affordable, the postponement will slow the adoption of new technologies, prevent the introduction of new services, and lose the potential productivity gains during the intervening time. The productivity gains from early adoption of higher speeds is 90% certain to exceed a present value of $550 million, and is expected to be $810 million.

In total, the net additional benefit from choosing the high speed network proposed by ISTC is 90% certain to exceed additional costs by a present value of $1.14 billion, and is expected to be $1.49 billion.

The real rate of return on the additional investment is 90% certain to exceed 44.8%, and is expected to be 53.2%. The likelihood of failing the Treasury Board guideline rate of return of 10% is negligible.

3. **Yes, there is a good rationale for government sponsorship.**

The alternative to government sponsorship is private sector provision. The early introduction of a high speed network is not feasible on a private sector basis. The break-even year (revenues meeting operating costs) is 90% certain to exceed year 9 of operation, and is expected to be year 10. Because of the length of time until break-even, and because the first market entrant is disadvantaged by the costs of market-making, private sector firms are very unlikely to offer a high-speed network.

In addition, sponsorship of the network furthers these public goals. Network sponsorship:

- Promotes and supports R&D without having to screen projects.
- Demonstrates the productivity impact of new technologies, encouraging rapid adoption.
- Compensates for market imperfections including the overestimation of training costs and the joint benefits of wide participation in a network.
- Creates a market-place for the competitive provision and development of information-related services.

Each of the above considerations is a rationale for government sponsorship because it promotes industrial productivity and development, and because its benefits cannot be captured by a private sector network provider.

Therefore, the high speed communications network for Canadian research & development proposed by ISTC is a project with significant positive returns and a good candidate for government sponsorship.

APPENDIX A: ALPHABETICAL GLOSSARY OF VARIABLES

The acronyms below represent variables employed in the benefit/cost model. Appendix B describes the equation set in which the variables are used, and lists the variables by equation module. The list below is alphabetic.

SUBSCRIPTS

t = time period (1 to 20 -- years 1991 to 2010)
i = r&d user category (3 -- private, government, institution)
b = test-bed user category (2 -- equipment, services)
a = application class (5)

VARIABLES

$AVPROD_t$ = The average productivity impact of the network on all R&D expenditure in Canada.

$AVUP_t$ = The proportion of all Canadian R&D currently on the network.

$BENITC_{bt}$ = The benefit to consumers of products from IT user group b in year t.

$BENITP_{bt}$ = The benefit to producers of products from IT user group b in year t, excluding additional costs of R&D.

$BNCNDF_{bt}$ = A conditional variable indicating whether benefits are positive in the year (t+LAG).

$BNCOND_{bt}$ = A conditional varialbe indicating whether benefits are positive in year t.

$BNITPT_{bt}$ = Net benefits in year t stemming from IT group b.

DDISC = A technical variable used to discount benefits in the 21st and subsequent years.

DISCPB = The social discount rate.

DISCPR = The average cost of capital in the private sector (private sector discount rate).

$EDIT_B$ = Elasticity of Demand for IT user category b.

$ESIT_B$ = Elasticity of Supply for IT user category b.

EXPT = The proportion of IT sales exported.

HWCOST = The annualized hardware cost borne by the user for each R&D worker. This cost is based on a depreciation rate sufficiently high to allow regular replacement with up-to-date technology. The discount rate employed is the public discount rate.

HWCSTP = Cost per user for hardware as perceived by individual firms. Same as HWCOST except private discount rate employed.

HWPROP = The proportion of total dollars IT sales that are equipment IT user category (the balance are service IT user category).

$INCBAS_b$ = The initial percentage increase in sales from access to network test-bed possibilities for IT user group b at time $TITST_b$.

$INCCST_t$ = The increased cost under ISTC sponsorship.

INCIRR = The internal rate of return from the increased benefits of ISTC sponsorship, given the increased costs.

$INCITB_t$ = The increase in IT benefits through test-bed use under ISTC sponsorship. This is the same as gross benefits since the reference case does not allow for test-bed users.

$INCMAT_b$ = The mature percentage increase in sales from access to the network for It user group b at time $TITFIN_b$.

INCNPVCST = Increase in present value of Network costs.

INCNPVITB = Increase in present value of IT benefits.

INCNPVRDB = Increase in present value of R&D productivity benefits.

$INCNTB_t$ = The sum of increased benefits, net of the costs of the respective networks.

$INCRDB_t$ = The increase in R&D productivity benefits under ISTC sponsorship.

IRR = The internal rate of return from the generation of benefits, given the forecast stream of costs.

$ITPAY_{bt}$ = Willingness to pay for test-bed access by IT user group b in year t.

$ITPAYR_b$ = The proportion of willingness to pay that can be recovered. It is less than one due to limitations in pricing.

$ITPAY_t$ = Willingness to pay for test-bed access by the IT industry in year t.

$ITSAL_{bt}$ = The increase in sales from access to the network for IT group b in year t.

$ITSALF_{bt}$ = The increase in sales from access to the network for IT group b in year (t + LAG).

LAG = The lag in years between R&D expenditure and impact on sales.

NPV = The net present value of the network project.

NPVCST = The net present value of the cost of the network.

NPVITB = The net present value of the benefits to IT users.

NPVRDB = The net present value of the benefits to R&D users.

$NTBEN_t$ = Net benefits of the network in year t.

$NTCST_t$ = The cost of the network in years 6 to 20.

$NTCST_t$ = The cost of the network in years 1 to 5.

$NTITB_t$ = Net benefits in year t stemming from IT use of the network.

$NTRDB_t$ = Net benefits of the network to R&D users in year t.

PAY_t = Willingness to pay by R&D users and IT users in year t.

$PBEN_{it}$ = Net private benefit for category i in year t.

PEN_{ait} = The proportion of R&D workers in user category i who are regular users of application a, out of those users in category i who have access to the network during time t (e.g. a subset of those indicated by UPTAKE).

$PENBAS_{ai}$ = The proportion of R&D workers in user category i who are regular users of application a, out of those users in category i who have access to the network at time $TSTART_a$.

$PENGR_{ai}$ = The rate of growth in PEN_{ait} between year $TSTART_a$ and year $TFIN_a$.

$PENMAT_{ai}$ = The proportion of R&D workers in user category i who are regular users of application a, out of those users in category i who have access to the network at time $TFIN_a$.

PHEAD = Willingness to pay expressed on a per head basis. Values are derived from immediate projections of educational institution demand for CANET.

$PRBAS_{ai}$ = The initial productivity gain in user category i from application group a when that application group becomes practically available.

$PRCOND_a$ = A dummy variable to indicate that application group a is available during year t.

$PRGR_{ai}$ = Annual growth rate in productivity impact of application group a on user category i.

$PRMAT_{ai}$ = The productivitity impact of a mature system of application a on on user group i. Mature system refers to a t3 system with mature user base.

$PROD_{ait}$ = The percentage productivity gain in user category i from application group a for year t.

$PTRAIN_t$ = The probability that a new worker will have to be trained to use the network, as percieved by individual firms.

PYRPR = Reduction in willingness to pay due to limitations in pricing mechanisms.

$RDBAS_i$ = Spending on R&D by user category i in the base year.

$RDBENI_{it}$ = Dollar value of productivity gains from the network to user category i in year t.

$RDBEN_t$ = Total dollar value of productivity gains for all R&D users.

$RDCOSTB_{it}$ = Total percieved dollar cost to users in time t, where capital expenditures are adjusted to annual flows based on a private sector discount rate.

$RDCOST_{it}$ = Total dollar cost to users in time t, where capital expenditures are adjusted to annual flows based on social discount rate.

$RDGR_t$ = The growth in R&D spending for year t.

$RDPYPB_t$ = The total willingness to pay by R&D users for network services in year t, given network prices.

$RDPYPB_t$ = Willingness to pay by public sector R&D users.

$RDPYPR_t$ = Willingness to pay by private sector R&D user category i.

$RDUSI_{it}$ = The number of R&D workers who have network access in user category i for year t.

$RDUZBS_i$ = The number of R&D workers in user category i in the base year.

$RDUZR_t$ = The total number of R&D workers who have network access in year t.

$SALBAS_b$ = The volume of sales for IT user group b in the base year.

$SALGRF_{bt}$ = The growth in sales fro IT user group b in year year (t+LAG) stemming from access to the network.

$SALINC_b$ = The annual rate of increase in the increase in sales between the years $TITST_b$ and $TITFIN_b$.

SALTOT = Total sales for IT users in the base year.

SBMULT = Social Benefit multiplier. Represents the marginal benefit of a dollar spent on R&D. This is greater than a dollar because of known underspending on R&D.

$SURPLS_t$ = Excess of willingness to pay over costs in year t.

$TFIN_a$ = The horizon year for application a productivity growth.

$TITFIN_b$ = The year in which the increase in sales from access to the network reaches a mature level for IT user group b.

$TITST_b$ = The year in which an impact on sales from access to the network begins for IT user group b.

TRCOST = The cost of training an R&D user to fully incorporate the network into their work-style. Includes the normal amount of time spent learning while using.

$TSTART_a$ = The first year when application group a has an impact on productivity.

$TUPFIN_i$ = The year when network participation reaches maturity for user category i.

$TUPST_i$ = The year when network participation effectively begins for user category i.

TURN = The overall turnover in Canada's R&D labour force.

$TURNP_i$ = The rate of R&D worker turnover for the average firm in user category i.

$UPBAS_i$ = The proportion of R&D within category that subscribes to the network in the initial year $TUPST_i$.

$UPCOND_i$ = A dummy variable to indicate that user category i is now able to use network in year t.

$UPGR_i$ = Annual growth rate in network participation rate for application i in the years before maturity.

$UPMAT_i$ = The proportion of R&D within category that subscribes to to the network when use reaches maturity, year $TUPFIN_i$.

$UPTAKE_{it}$ = The proportion of R&D now accessible to network for user category i in year t.

APPENDIX B: BENEFIT/COST ESTIMATION MODEL

The model used to estimate benefits and costs of the Network is described below. The model is divided into eight modules:

- R&D User Benefits
- R&D User Costs
- R&D Willingness to Pay
- IT Benefits & Costs
- IT Willingess to Pay
- Network Costs
- Net Benefits
- Incremental Impact

The input and output variables used for module are defined, followed by a table defining their mathematical relationship. A description of the principles employed in each module is provided in Chapter 5.

SUBSCRIPTS USED BY VARIABLES

t = time period (20 -- years 1991 to 2010)
i = r&d user category (3 -- private, government, institution)
b = test-bed user category (2 -- equipment, services)
a = application class (5)

R&D USER BENEFITS MODULE

Input Variables

$PENBAS_{ai}$ = The proportion of R&D workers in user category i who are regular users of application a, out of those users in category i who have access to the network at time $TSTART_a$.

$PENMAT_{ai}$ = The proportion of R&D workers in user category i who are regular users of application a, out of those users in category i who have access to the network at time $TFIN_a$.

$PRBAS_{ai}$ = The initial productivity gain in user category i from application group a when that application group becomes practically available.

$PRMAT_{ai}$ = The productivitity impact of a mature system of application a on on user group i. Mature system refers to a t3 system with mature user base.

$RDBAS_i$ = Spending on R&D by user category i in the base year.

SBMULT = Social Benefit multiplier. Represents the marginal benefit of a dollar spent on R&D. This is greater than a dollar because of known underspending on R&D.

$TUPFIN_i$ = The year when network participation reaches maturity for user category i.

$TUPST_i$ = The year when network participation effectively begins for user category i.

$TFIN_a$ = The horizon year for application a productivity growth.

$TSTART_a$ = The first year when application group a has an impact on productivity.

$UPBAS_i$ = The proportion of R&D within category that subscribes to the network in the initial year $TUPST_i$.

$UPMAT_i$ = The proportion of R&D within category that subscribes to to the network when use reaches maturity, year $TUPFIN_i$.

Generated Variables

$AVPROD_t$ = The average productivity impact of the network on all R&D expenditure.

$AVUP_t$ = The proportion of all Canadian R&D currently on the network.

PEN_{ait} = The proportion of R&D workers in user category i who are regular users of application a, out of those users in category i who have access to the network during time t (e.g. a subset of those indicated by UPTAKE).

$PENGR_{ai}$ = The rate of growth in PEN_{ait} between year $TSTART_a$ and year $TFIN_a$.

$PRCOND_a$ = A dummy variable to indicate that application group a is available during year t.

$PRGR_{ai}$ = Annual growth rate in productivity impact of application group a on user category i.

$PROD_{ait}$ = The percentage productivity gain in user category i from application group a for year t.

$RDBENI_{it}$ = Dollar value of productivity gains from the network to user category i in year t.

$RDBEN_t$ = Total dollar value of productivity gains for all R&D users.

$RDGR_t$ = The growth in R&D spending for year t.

$UPCOND_i$ = A dummy variable to indicate that user category i is now able to use network in year t.

$UPGR_i$ = Annual growth rate in network participation rate for application i in the years before maturity.

$UPTAKE_{it}$ = The proportion of R&D now accessible to network for user category i in year t.

TABLE B-1
R & D USER BENEFITS

$RDBEN_t = \Sigma_i \; RDBENI_{it}$

$RDBENI_{it} = RDBAS_i * RDGR_t * SBMULT * UPTAKE_{it} \; (\Sigma_a \; PROD_{ait} * PEN_{ait})$

$PROD_{ait} = PRCOND_a * PRBAS_{ai} * PRGR_{ai}^{(t-TSARTi)}$ if $t < TFIN_a$

$= PRCOND_a * PRBAS_{ai} * PRGR_{ai}$ if $t \geq TFIN_a$

$PRGR_{ai} = \exp \; [\ln \; (PRMAT_{ai}/PRBAS_{ai})/(TFIN_a - TSTART_{a)}]$

$PEN_{ait} = PRCOND_a * PENBAS_{ai} * PENGR_{ai}^{(t-TSTARTa)}$ if $t < TFIN_a$

$= PRCOND_a * PENMAT_{ai}$ if $t \geq TFIN_a$

$PENGR_{ai} = \exp \; [\ln \; [PENMAT_{ai} \backslash PENBAS_{ai}]/(TFIN_a - TSTART_a)]$

$UPTAKE_{it} = UPCOND_i * UPBAS_i * UPGR_i^{(t-TUPSTi)}$ if $t \leq TUPFIN$

$= UPMAT_i$ if $t > TUPFIN_i$

$UPGR_i = \exp \; [\ln \; [UPMAT_i/UPMAS_i]/(TUPFIN_i - TUPST_i)]$

$UPCOND_i = 1$ if $t \geq TUPST_i$

$= 0$ if $t < TUPST_i$

$PRCOND_a = 1$ if $t \geq TSTART_a$

$= 0$ if $t < TSTART_a$

$AVUP_t = \Sigma_i \; UPTAKE_{it} * [RDBAS_i/\Sigma_i RDBAS_i]$

$AVPROD_i = \Sigma_i \; UPTAKE_{it} \; [\Sigma \; PROD_{ait} * PEN_{ait}] * [RDBAS_i/\Sigma \; RDBAS_i]$

R&D USER COSTS MODULE

Input Variables

DISCPB = The social discount rate.

HWCOST = The annualized hardware cost borne by the user for each R&D worker. This cost is based on a depreciation rate sufficiently high to allow regular replacement with up-to-date technology. The discount rate employed is the public discount rate.

$RDUZBS_i$ = The number of R&D workers in user category i in the base year.

TRCOST = The cost of training an R&D user to fully incorporate the network into their work-style. Includes the normal amount of time spent learning while using.

TURN = The overall turnover in Canada's R&D labour force.

Generated Variables

$RDUSI_{it}$ = The number of R&D workers who have network access in user category i for year t.

$RDUZR_t$ = The total number of R&D workers who have network access in year t.

$RDCOST_{it}$ = Total dollar cost to users in time t, where capital expenditures are adjusted to annual flows based on social discount rate.

TABLE B-2
R & D USER COSTS
(Excluding Fees)

$$RDCOST_t = RDUZR_t * [HWCOST + TRCOST * DISCPB] + RDUZR_t * TURN * TRCOST * [1/(1-DISCPB)]$$

$$RDUZR = \Sigma_i \ RDUZI_{it}$$

$$RDUZI_{it} = RDUZBS_i * RDGR_t * UPTAKE_{it}$$

R&D WILLINGNESS TO PAY MODULE

Input Variables

DISCPR = The average cost of capital in the private sector (private sector discount rate).

HWCSTP = Cost per user for hardware as perceived by individual firms. Same as HWCOST except private discount rate employed.

PHEAD = Willingness to pay expressed on a per head basis, as derived from immediate projections of educational institution demand for CANET.

$TURNP_i$ = The rate of R&D worker turnover for the average firm in user category i.

PYRPR = Reduction in willingness to pay due to limitations in pricing mechanisms.

Generated Variables

DDISC = A technical variable used to discount benefits in the 21st and subsequent years.

$PBEN_{it}$ = Net private benefit for category i in year t.

$PTRAIN_t$ = The probability that a new worker will have to be trained to use the network, as percieved by individual firms.

$RDCOSTB_{it}$ = Total percieved dollar cost to users in time t, where capital expenditures are adjusted to annual flows based on a private sector discount rate.

$RDPYPB_t$ = The total willingness to pay by R&D users for network services in year t, given network prices.

$RDPYPB_t$ = Willingness to pay by public sector R&D users.

$RDPYPR_t$ = Willingness to pay by private sector R&D user category i.

TABLE B-3
R & D WILLINGNESS TO PAY

$RDPAY_t = RDPYPR_t + RDPYPB_t$

$RDPYPR_t = [\Sigma_{i=PR} PBEN_{it}] * PYRPR$

$RDPYPB_t = \Sigma_{i=PB} RDUZI * PHEAD$

$PBEN_{it} = RDBENI_{it}/SBMULT - RDCOST_{it}$

$RDCOST_{it} = RDUZI_{it} * HWCSTP + TRCOST * DISCPR * RDUZI_t + TRCOST$
$[RDUZ_{it} * TURNP_i * PTRAIN_{t-1}] * [1/(1-DISCPR)]$

$PTRAIN_t = [RDUZR_{t-1}/(\Sigma_i RDUZBS_i * RDGR_{t-1})]$

NOTES:

PR = Private Sector

PB = Government and Institutions

IT BENEFITS & COSTS MODULE

Input Variables

BGRAJ = Adjustment factor matching IT sales base year to R&D growth factor base year.

$EDIT_B$ = Elasticity of Demand for IT user category b.

$ESIT_B$ = Elasticity of Supply for IT user category b.

EXPT = The proportion of IT sales exported.

HWPROP = The proportion of total dollars IT sales that are equipment IT user category (the balance are service IT user category).

$INCBAS_b$ = The initial percentage increase in sales from access to network test-bed possibilities for IT user group b at time $TITST_b$.

$INCMAT_b$ = The mature percentage increase in sales from access to the network for It user group b at time $TITFIN_b$.

LAG = The lag in years between R&D expenditure and impact on sales.

SALTOT = Total sales for IT users in the base year.

$TITFIN_b$ = The year in which the increase in sales from access to the network reaches a mature level for IT user group b.

$TITST_b$ = The year in which an impact on sales from access to the network begins for IT user group b.

Generated Variables

$BENITC_{bt}$ = The benefit to consumers of products from IT user group b in year t.

$BENITP_{bt}$ = The benefit to producers of products from IT user group b in year t, excluding additional costs of R&D.

$BNCNDF_{bt}$ = A conditional variable indicating whether benefits are positive in the year (t+LAG).

$BNCOND_{bt}$ = A conditional varialbe indicating whether benefits are positive in year t.

$BNITPT_{bt}$ = Net benefits in year t stemming from IT group b.

$ITSAL_{bt}$ = The increase in sales from access to the network for IT group b in year t.

$ITSALF_{bt}$ = The increase in sales from access to the network for IT group b in year (t + LAG).

$NTITB_t$ = Net benefits in year t stemming from IT use of the network.

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$SALBAS_b$ = The volume of sales for IT user group b in the base year.

$SALGRF_{bt}$ = The growth in sales fro IT user group b in year year (t+LAG) stemming from access to the network.

$SALINC_b$ = The annual rate of increase in the increase in sales between the years $TITST_b$ and $TITFIN_b$.

TABLE B-4
IT BENEFITS & COSTS

$NTITB_t = \Sigma_b\ BNITPT_{bt}$

$BNITPT_{bt} = BENITC_{bt} + BENITP_{bt}$

$BENITC_{bt} = ITSAL_{bt} * [.5/EDIT_b] * EXPT$

$BENITP_{bt} = ITSAL_{bt} * [.5/ESIT_b]$

$ITSAL_{bt} = SALBAS_b * SALGR_{bt} * RDGR_t * BGRAJ * BNCOND_{bt}$

$SALGR_{bt} = INCBAS_b * SALINC_b^{(t-TITSTb)}$ if $t < TITFIN_b$

$= INCMAT_b$ if $t \geq TITFIN_b$

$SALINC_b = \exp [\ln[INCMAT_b/INCBAS_b]/(TITFIN_b - TITST_b)]$

$BNCOND_{bt} = 1$ if $t \geq TITST_b$

$= 0$ if $t < TITST_b$

$ITSALF_{bt} = SALBAS_b * SALGRF_{bt} * RDGR_{t+4} * BGRAJ * BNCNDF_{bt}$

$SALGRF_{bt} = INCBAS_b * SALINC^{(t-TITSTb + LAG)}$ if $t < TITFIN - LAG$

$= INCMAT_b$ if $t \geq TITFIN - LAG$

$BNCNDF_{bt} = 1$ if $t \geq (TITST_b - LAG)$

$= 0$ if $t < (TITST_b - LAG)$

$SALBAS_1 = SALTOT * HWPROP$

$SALBAS_2 = SALTOT * (1-HWPROP)$

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IT WILLINGNESS TO PAY MODULE

Input Variables

$ITPAYR_b$ = The proportion of willingness to pay that can be recovered. It is less than one due to limitations in pricing.

Generated Variables

$ITPAY_{bt}$ = Willingness to pay for test-bed access by IT user group b in year t.

$ITPAY_t$ = Willingness to pay for test-bed access by the IT industry in year t.

TABLE B-5
IT WILLINGNESS TO PAY
(For LAG = 4)

$ITPAY_t \quad = \Sigma_b \; ITPAY_{bt}$

$ITPAY_{bt} \quad = ITPYPR * [(A/(1+DISCPB)_4)*BENITP_{b,t+4}$

$\quad + (B/(1+DISCPB)_5)*BENITP_{b,t+5}$

$\quad + (C/(1+DISCPB)_6)*BENITP_{b,t+6)}$

$\quad + (D/PDISC)*BENITP_{b,t=20)}$

$A_t \quad = 0 \text{ if } t < (TITST_{bt} - 4)$

$\quad = 1 \text{ if } t = (TITST_{bt} - 4)$

$\quad = 1/3 \text{ if } (TITST_{bt} - 3) \leq t < 17$

$B_t \quad = 0 \text{ if } t < (TITST_{bt} - 4)$

$\quad = 2/3 \text{ if } t = (TITST_{bt} - 4)$

$\quad = 1/3 \text{ if } (TITST_{bt} - 3) \leq t < 16$

$C_t \quad = 0 \text{ if } t < (TITST - 4)$

$\quad = 1/3 \text{ if } (TITST_{bt} - 3) \leq t < 15$

$D_t \quad = 0 \text{ if } t < 14$

$\quad = 1/3 \text{ if } t = 15$

$\quad = 2/3 \text{ if } t = 16$

$\quad = 1 \text{ if } t \geq 17$

$DDISC = 1 \qquad \text{if } t < 14$

$\quad = (1 + DISCPB)^6 \qquad \text{if } t = 15$

$\quad = .5[(1+DISCPB)^6 + (1+DISCPB)^5] \qquad \text{if } t = 16$

$\quad = [(1+DISCPB)^6 + (1+DISCPB)^5 + (1+DISCPB)^4]/3 \qquad \text{if } t \geq 17$

NETWORK COST MODULE

Input Variables

$NTCST_t$ = The cost of the network in years 1 to 5.

Generated Variables

$NTCST_t$ = The cost of the network in years 6 to 20.

TABLE B-6
NETWORK COST

$NTCST_{t=1-5}$ = An Input Variable

$NTCST_{t=6-20}$ = $NTCST_5$ * ($RDUZR_t$/$RDVZR_{t=5}$)

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NET BENEFITS MODULE

Generated Variables

IRR	=	The internal rate of return from the generation of benefits, given the forecast stream of costs.
NPV	=	The net present value of the network project.
NPVCST	=	The net present value of the cost of the network.
NPVITB	=	The net present value of the benefits to IT users.
NPVRDB	=	The net present value of the benefits to R&D users.
$NTBEN_t$	=	Net benefits of the network in year t.
$NTRDB_t$	=	Net benefits of the network to R&D users in year t.
PAY_t	=	Willingness to pay by R&D users and IT users in year t.
$SURPLS_t$	=	Excess of willingness to pay over costs in year t.

TABLE B-7
NET BENEFITS

$NPV = NPVRDB + NPVITB - NPVCST$

$NPVITB = [\Sigma_t (NTITB_t/(1 - DISCPB)^t)] + (NTITB_{20}/DISCPB * (1 + DISCPB)^{20})$

$NPVCST = [\Sigma_t (NTCST_t/(1 - DISCPB)^t)] + (NTCST_{20}/DISCPB * (1 + DISCPB)^{20})$

$NPVRDB = [\Sigma_t (NTRDB_t/(1 - DISCPB)^t)] + (NTRDB_{20}/DISCPB * (1 + DISCPB)^{20})$

$NTRDB_t = RDBEN_t - RDCOST_t$

$NTBEN_t = NTRDB_t + NTITB_t - NTCST_t$

$PAY_t = ITPAYT_t + RDPYPR_t + RDPYPB_t$

$SURPLS_t = PAY_t - NTCST_t$

INCREMENTAL BENEFITS MODULE
(ISTC less the reference case)

Generated Variables

$INCRDB_t$ = The increase in R&D productivity benefits under ISTC sponsorship.

$INCITB_t$ = The increase in IT benefits through test-bed use under ISTC sponsorship. This is the same as gross benefits since the reference case does not allow for test-bed users.

$INCNTB_t$ = The sum of increased benefits, net of the costs of the respective networks.

$INCCST_t$ = The increased cost under ISTC sponsorship.

INCNPVRDB = Increase in present value of R&D productivity benefits.

INCNPVITB = Increase in present value of IT benefits.

INCNPVCST = Increase in present value of Network costs.

INCIRR = The internal rate of return from the increased benefits of ISTC sponsorship, given the increased costs.

TABLE B-8
INCREMENTAL IMPACT

[=(ISTC minus the reference case)]

INCNPV	= INCNPVRDB + INCNPVITB - INCNPVCST
INCRD	= INCNPVRDB - INCNPVCST
INCNPVRDB	$= [\Sigma_t(INCITB_t/(1+DISCPB)^t)] + [INCRDB_{20}/(DISCPB *(1 + DISCPB)^{20})]$
INCNPVITB	$= [\Sigma_t(INCITB_t/(1 + DISCPB)^t)] + [INCITB_{20}/(DISCPB(1 + DISCPB)^{20})]$
INCNPVCST	$= [\Sigma_t(INCCST_t/(1 + DISCPB)^t)] + [INCST_{20}/(DISCPB(1 + DISCPB)^{20})]$
$INCRDB_t$	$= NTRDB_t$
$INCITB_t$	$= NTITB_t$
$INCNTB_t$	$= NTBEN_t$
$INCCST_t$	$= NTCST_t$

APPENDIX C: INPUT VALUE RANGES

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INTRODUCTION

The benefit/cost model documented in Appendix B was subjected to a Monte Carlo simulation, through HICKLING's Risk Analysis Process (RAP). This approach is described in Chapter 4 on methodology.

RAP accomodates uncertainty about key values by permitting a probability distribution to be assigned instead of a fixed number.

Each input value was assigned a probability distribution based on its most likely value, plus an 80% confidence interval. The form of the distribution was triangular, in order to allow asymettrical distributions. The central value chosen was treated as the mode, or top of the triangle. The probability distribution was then calculated so that 80% of the area fell between the low and high values of the confidence interval, 10% of the area fell below the lower bound, and 10% of the area fell above the upper bound.[1]

The expert panel and the project team were required to choose a most likely value, to set a 10% number such that the value of the variable is likely to fall below it only one out of ten times, and to set a 90% number such that the value of the variable is likley to fall above it only one out of ten times.

This appendix reports on the upper, central, and lower limits chosen for each of the input variables.

The variables are presented in eleven tables. Accompanying the tables are written descriptions of the variables and the values chosen for them. These descriptions contain the following information:

- Variable name and description
- Benefit/Cost Module for which it was used
- The values chosen and the reasons behind that choice

The tables are divided by application groups, users, industry groups, economic growth indicators and other inputs. Inputs were made for both the ISTC network and for the reference case.

The organization of the tables is dictated by the model entry requirements. For example, variables which had different values for both application and user group (subscripts a and i) appear in the same tables.

In most cases, the same values were used for the ISTC network and the reference case. Where different values are used for the reference case, a separate table is provided. The key differences between the evaluation of the ISTC network and the reference case are summarized in Chapter 5.

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[1]In cases where a specific bound was desired, such as not less than zero, the upper and lower bounds where chosen to represent a 100% confidence interval.

RAP INPUTS BY APPLICATION GROUP - ISTC NETWORK & THE REFERENCE CASE TABLES C - 1.1 AND C - 1.2

Introduction

Tables C - 1.1 and C - 1.2 (see following two pages) depict starting times and horizon times by application group for both the ISTC network and the reference case. In the following section the variables under each alternative are identified, defined and the reasons for assigning values to them are described. First the values for the ISTC network variables were determined. Subsequently the values of the variables under the reference case were defined relative to those of the ISTC network.

Regarding the reference case values, the following should be noted. Values chosen for start times indicate the number of additional years required under the reference case to achieve productivity increases. Values chosen for horizon times indicate the number of additional years required under the reference case to achieve productivity increases. Per person impacts are estimated to be the same under both networks, however uptake numbers and speed will have an impact. Under the reference case, marketing is a weak force. This is assumed to have an impact on horizon times for productivity growth under the reference case. Not all applications will lag to the same degree. The reasons for the differences among the applications are presented below.

Variable Name(s): $TSTART_1$ Starting Time - Application 1 (E-Mail, time-slipped communications)

Description: The first year when Slipped-time applications group (E-Mail) has an impact on productivity.

Module(s): R&D User Benefits

Reasons for Values Chosen: *ISTC Network.* E-Mail and other time-slipped applications are already in wide use in LANs and other networks. The capacity required to operate the application is presently sufficient. Thus productivity increases for time-slipped applications would be realized from year 1.

Reference Case. Capacity exists currently, therefore productivity increases under the reference case will begin at the same time as ISTC.

Values Chosen (10%-M-90%): Fixed value, year 1 for ISTC network
Fixed value, + 0 years for the reference case

TABLE C - 1.1

RAP INPUTS
BY APPLICATION GROUP

ISTC NETWORK

Application Group	Starting Time ($TSTART_a$)			Horizon Time ($TFIN_a$)		
	10%	M	90%	10%	M	90%
1		1		4	6	10
2		1		8	10	15
3		1		3	4	5
4	6	8	12	13	15	20
5	1	2	3	7	13	20

TABLE C - 1.2

RAP INPUTS
APPLICATIONS

REFERENCE CASE
(Incremental)

Application Group	Starting Time ($TSTART_a$)			Horizon Time ($TFIN_a$)		
	10%	M	90%	10%	M	90%
1		+0		+4	+5	+6
2		+0		+4	+5	+6
3		+0		+2	+3	+4
4	+3	+4	+5	+6	+7	+8
5		+1		+2	+3	+4

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RAP INPUTS BY APPLICATION GROUP - ISTC NETWORK & THE REFERENCE CASE TABLES C - 1.1 AND C - 1.2 (CONT'D)

Variable Name(s): $TSTART_2$ Starting Time - Application 2 (Virtual Terminal)

Description: The first year when virtual terminal application group has an impact on productivity.

Module(s): R&D User Benefits

Reasons for Values Chosen: *ISTC Network.* The technology required for virtual terminal applications is already available. The capacity required to operate the application is presently sufficient. Thus productivity increases form virtual terminal applications would be realized from year 1.

Reference Case. As for application 1.

Values Chosen (10%-M-90%): Fixed value, year 1 for ISTC network
Fixed value, + 0 years for the reference case

Variable Name(s): $TSTART_3$ Starting Time - Application 3 (File Transfers)

Description: The first year when file transfers applications has an impact on productivity.

Module(s): R&D User Benefits

Reasons for Values Chosen: *ISTC Network.* The technology required for file tranfers is already available. The capacity required to operate the application is presently sufficient. Large files can be transferred on the existing 56 k facilities, although at cumbersome speeds. Larger transfers will be possible at higher speed as the network is upgraded. Thus productivity increases from file transfer applications would be realized from year 1.

Reference Case. As for application 1.

Values Chosen (10%-M-90%): Fixed value, year 1 for ISTC network
Fixed value, + 0 years for the reference case

RAP INPUTS BY APPLICATION GROUP - ISTC NETWORK & THE REFERENCE CASE TABLES C - 1.1 AND C - 1.2 (CONT'D)

Variable Name(s): $TSTART_4$ Starting Time - Application 4 (Real-time, Video conferencing)

Description: The first year when real-time applications group has an impact on productivity. It includes, screen, voice, and ultimately, vision.

Module(s): R&D User Benefits

Reasons for Values Chosen: *ISTC Network.* This, of all the applications, needs the highest network capacity and will have the slowest user uptake. These factors combine to determine that increases from real-time applications could be realized from year 8.

Reference Case. Because of the lag in acquiring the necessary network speed, and the lower staff time devoted to service development, introduction of these applications on the reference case is expected to be at 3 to 5 years later. Three years represents one cycle of capital replacement.

Values Chosen (10%-M-90%): Years 6 - 8 - 12 for ISTC network
+3 +4 +5 years for the reference case

Variable Name(s): $TSTART_5$ Starting Time - Application 5 (Databases)

Description: The first year when database application group has an impact on productivity.

Module(s): R&D User Benefits

Reasons for Values Chosen: *ICST Proposal.* The principal initial productivity impact will come from the provision of a single point of access for current on-line data-base services. This will not be provided on the network until year 2 because of the necessary administrative delay to make commercial arrangements and ensure underlying software compatibility of diverse private services.

Reference Case. Because of the lower budget, a lower staffing level is assumed. This means that the administrative and technical delays in making on-line services conveniently available is There is a strong motivation requirement for getting database services on-line will likely take an extra year.

Values Chosen (10%-M-90%): Years 1 - 2 - 3 for ISTC network
+1 year for the reference case

RAP INPUTS BY APPLICATION GROUP - ISTC NETWORK & THE REFERENCE CASE TABLES C - 1.1 AND C - 1.2 (CONT'D)

Variable Name(s): $TFIN_1$ Horizon Time - Application 1 (E-Mail, time-slipped communications)

Description: The horizon year for Slipped-time applications group (E-Mail) productivity growth.

Module(s): R&D User Benefits

Reasons for Values Chosen: *ISTC Network.* This application will have one of the shortest paths to maturity because it is already in fairly wide use and should have a high rate of uptake.

Reference Case. Mean lag is five years, although possibly less in government. Lower network speeds and less staff time to promote the services and make them convenient will delay reaching maturity.

Values Chosen (10%-M-90%): Years 4 - 6 - 10 for ISTC network
+4 +5 +6 years for the reference case

Variable Name(s): $TFIN_2$ Horizon Time - Application 2 (Virtual terminal)

Description: The horizon year for virtual terminal applications group productivity growth.

Module(s): R&D User Benefits

Reasons for Values Chosen: *ISTC Network.* It is expected to take roughly a decade for this application to reach maturity. Maturity includes the development of a service market for specialized information and information processing services.

Reference Case. Mean lag is five years. The service sharing possibilities require significant network speeds, placing the reference case at least one capital renewal cycle (3 years) behind the ISTC network. In addition there is the impact of less available staff time.

Values Chosen (10%-M-90%): Years 8 - 10 - 15 for ISTC network
+4 +5 +6 years for the reference case

RAP INPUTS BY APPLICATION GROUP - ISTC NETWORK & THE REFERENCE CASE TABLES C - 1.1 AND C - 1.2 (CONT'D)

Variable Name(s): $TFIN_3$ Horizon Time - Application 3 (File transfer)

Description: The horizon year for file transfer applications group productivity growth.

Module(s): R&D User Benefits

Reasons for Values Chosen: *ISTC Network.* File transfer is the most commonly used existing application. Uptake rate and frequency of use will both be high, therefore the time to reach maturity will be short.

Reference Case. Here the lag will be only 3 years representing the capital renewal cycle. It will take one cyle longer to achieve the network speeds required for mature productivity impact from large file transfer.

Values chosen (10%-M-90%): Years 3 - 4 - 5 for ISTC network
+ 2 +3 +4 for the reference case

Variable Name(s): $TFIN_4$ Horizon Time - Application 4 (Real-time, video conferencing)

Description: The horizon year for Real-time (Video conferencing) applications group productivity growth.

Module(s): R&D User Benefits

Reasons for Values Chosen: *ISTC Network.* Reaching maturity is expected to take the longest for this alternative. Although some forms of real-time interaction, such as on screen, are available immediately, and voice is relatively easy to add, significant real time screen interaction and video interaction will require both high speeds (T3 minimum for transmission of moving pictures) hardware upgrades by users and development work by the network.

Reference Case. The significant requirements of full screen-voice-video interaction for network speed and development time by staff are anticipated to add 7 years to the maturity date for the reference case.

Values Chosen (10%-M-90%): Years 13 - 15 - 20 for ISTC network
+ 5 +7 +8 years for the reference case

RAP INPUTS BY APPLICATION GROUP - ISTC NETWORK & THE REFERENCE CASE TABLES C - 1.1 AND C - 1.2 (CONT'D)

Variable Name(s): $TFIN_5$ Horizon Time - Application 5 (Databases)

Description: The horizon year for database applications group productivity growth.

Module(s): R&D User Benefits

Reasons for Values Chosen: *ISTC Network*. Although strong data-base services are available at present, there is substantial progress still to be made in integrating the world's data and providing searching techniques that are easily accessible to users. In addition, the development of a new market in specialty databases on the research network will take time. In its mature phase, data-base services may include hyper-text and digital libaries with complete access to full-text on screen. The network speed necessary to support this level of service is well beyond current capacities, as is the current level of service development.

Reference Case. With the existence of a strong private sector data-base service industry, service development time should not be a constraint over the long run. The handicap of the reference case will be network speed. Here the lag will be only 3 years (one equipment replacement cycle).

Values Chosen (10%-M-90%): Years 7 - 13 - 20 for ISTC network
+2 +3 +4 years for the reference case

TABLE C - 1.3

RAP INPUTS
BY APPLICATION * USER

ISTC NETWORK & REFERENCE CASE
(Productivity)

Variable	Variable Name	Private Sector			Government			Institutions		
		10%	M	90%	10%	M	90%	10%	M	90%
Initial Productivity Impact 1	$PRBAS_{1i}$	0	.025	.05	0	.0375	.05	0	.0375	.05
Initial Productivity Impact 2	$PRBAS_{2i}$	.05	.10	.15	.05	.10	.15	.05	.10	.15
Initial Productivity Impact 3	$PRBAS_{3i}$	0	.0025	.005	0	.005	.01	0	.005	.01
Initial Productivity Impact 4	$PRBAS_{4i}$	.01	.02	.04	.01	.02	.04	.01	.02	.04
Initial Productivity Impact 5	$PRBAS_{5i}$	.01	.02	.03	.01	.02	.03	.01	.02	.03
% Mature Productivity Impact 1	$PRMAT_{1i}$	0	.05	.10	0	.075	.10	0	.075	.10
% Mature Productivity Impact 2	$PRMAT_{2i}$	.10	.20	.30	.10	.20	.30	.10	.20	.30
% Mature Productivity Impact 3	$PRMAT_{3i}$	0	.005	.01	0	.01	.02	0	.01	.02
% Mature Productivity Impact 4	$PRMAT_{4i}$	.03	.06	.12	.03	.06	.12	.03	.06	.12
% Mature Productivity Impact 5	$PRMAT_{5i}$	.02	.03	.04	.02	.03	.04	.02	.03	.04

RAP INPUTS BY APPLICATION * USER
TABLES C - 1.3 (PRODUCTIVITY IMPACT) AND C - 1.4 (PENETRATION)

Introduction

This section deals with two elements of productivity increase. First there is the productivity increase anticipated for active network users of a given application group. Second, there is the question of how many network users will be active users of that application. This is referred to as the "penetration" of the service. The questions of productivity impacts and penetration were dealt with separately for the private sector on the one hand, and government and institutions on the other. The latter grouping includes government, universities and private non-profit research organizations.

A theme in the productivity assessment is that government and institutions have a greater need for communications and collaboration, and consequently recieve higher productivity gains from the network. Government R&D is intended for sharing with the rest of the economy, and it is the nature of university work to be collaborative. The higher need in the public sector is confirmed by the public sector user motivation behind the reference case.

TABLE C - 1.3 PRODUCTIVITY IMPACT

Variable Name(s): $PRBAS_{1i}$ Initial productivity gain - Application 1 (E-Mail, time-slipped communications), Private sector and institutional users.

Description: The initial productivity gain in both user categories from time-slipped communications application group when that application group becomes practically available.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Initial productivity gain will likely be significant, since the technology and user-interfaces of E-mail and other applications are well developed.

Values Chosen (10%-M-90%): 0 - 2.5% - 5%

Government/institutions. These users are likely to be subject to a faster institutional learning curve so the productivity impact will be slightly higher. They also have a higher need for communications and collaboration.

Values Chosen (10%-M-90%): 0 - 3.75% - 5%

Variable Name(s): $PRBAS_{2i}$ Initial productivity gain - Application 2 (Virtual Terminal), Private sector and institutional users.

Description: The initial productivity gain in both user categories from virtual terminal application group when that application group becomes practically available.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector and Government/institutions.* For those who require remote access to facilities, this feature of the Network is very important. The numbers of regular users (initial penetration rates), on the other hand, are expected to be low (see further below).

Values Chosen (10%-M-90%): 5% - 10% - 15%

RAP INPUTS PRODUCTIVITY IMPACT BY APPLICATION * USER
TABLE C - 1.3 (CONT'D)

Variable Name(s): $PRBAS_{3i}$ Initial productivity gain - Application 3 (File Transfers), Private sector and institutional users.

Description: The initial productivity gain in both user categories from file transfer application group when that application group becomes practically available.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Based on one half of the expected mature productivity due to slower current speed of network.

Values Chosen (10%-M-90%): 0 - .25% - .5%

Government/institutions. Based on one half of the expected mature productivity due to slower current speed of network.

Values Chosen (10%-M-90%): 0 - .5% - 1%

Variable Name(s): $PRBAS_{4i}$ Initial productivity gain - Application 4 (Real-time, video conferencing), Private sector and institutional users.

Description: The initial productivity gain in both user categories from real-time application group when that application group becomes practically available.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* When this application comes to be available, it is expected tor reduce and or substitute the need for travel and enhance interaction between R&D workers. Technology for full voice and video remote conferencing is available in some locations now, but is not anticipated to have initial wide-spread use at that level.

Values Chosen (10%-M-90%): 1% - 2% - 4%

Government/institutions. As for private sector.

Values Chosen (10%-M-90%): 1% - 2% - 4%

RAP INPUTS PRODUCTIVITY IMPACT BY APPLICATION * USER
TABLE C - 1.3 (CONT'D)

Variable Name(s): $PRBAS_{5i}$ Initial productivity gain - Application 5 (Databases), Private sector and institutional users.

Description: The initial productivity gain in both user categories from database application group when that application group becomes practically available.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Initial productivity impact will be significant due to the well developed nature of some current services.

Values Chosen (10%-M-90%): 1% - 2% - 3%

Government/institutions. As for private sector.

Values Chosen (10%-M-90%): 1% - 2% - 3%

Variable Name(s): $PRMAT_{1i}$ Mature productivity gain - Application 1 (E-Mail, time-slipped communications), Private sector and institutional users.

Description: The productivitity impact of a mature system of application 1 on on both user groups. Mature system refers to a t3 system with mature user base.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Mature productivity under this application will be twice the initial as potentail for use increases.

Values Chosen (10%-M-90%): 0 - 5% - 10%

Government/institutions. As for private sector

Values Chosen (10%-M-90%): 0 - 7.5% - 10%

RAP INPUTS PRODUCTIVITY IMPACT BY APPLICATION * USER
TABLE C - 1.3 (CONT'D)

Variable Name(s): $PRMAT_{2i}$ Mature productivity gain - Application 2 (Virtual Terminal), Private sector and institutional users.

Description: The productivitity impact of a mature system of application 2 on on both user groups. Mature system refers to a t3 system with mature user base.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector*. As the market for sharing facilities and providing specialized information and information processing services developes, this application is expected to double in its productivity impact on regular users.

Values Chosen (10%-M-90%): 10% - 20% - 30%

Government/institutions. As for private sector

Values Chosen (10%-M-90%): 10% - 20% - 30%

Variable Name(s): $PRMAT_{3i}$ Mature productivity gain - Application 3 (File Transfers), Private sector and institutional users.

Description: The productivitity impact of a mature system of application 3 on on both user groups. Mature system refers to at least a T3 system with mature user base.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector*. Productivity will double as file sizes and applications get larger.

Values Chosen (10%-M-90%): 0 - .5% - 1%

Government/institutions. Governent productivity impacts will be greater due to high level of collaboration and communication needs.

Values Chosen (10%-M-90%): 0 - 1% - 2%

RAP INPUTS PRODUCTIVITY IMPACT BY APPLICATION * USER
TABLE C - 1.3 (CONT'D)

Variable Name(s): $PRMAT_{4i}$ Mature productivity gain - Application 4 (Real-time, video conferencing), Private sector and institutional users.

Description: The productivitity impact of a mature system of application 4 on on both user groups. Mature system refers to at least a T3 system with mature user base.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Productivity impact will be significant largely due to the time savings associated with lower travel requirements which will ensue from this application. An increase of a factor of three is anticipated as more mature versions of the applications become available.

Values chosen (10%-M-90%) 3% - 6% - 12%

Government/institutions. As for private sector

Values chosen (10%-M-90%) 3% - 6% - 12%

Variable Name(s): $PRMAT_{5i}$ Mature productivity gain - Application 5 (Databases), Private sector and institutional users.

Description: The productivitity impact of a mature system of application 5 on on both user groups. Mature system refers to a t3 system with mature user base.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Increased availability of data and improved user interfaces and search tools will increase the expected productivity impact by 50% over the initial impact. Small business which has been information-deprived will see the strongest productivity increases. Problems in the private sector, such as maintaining catalogue rooms of materials specifications, will be eliminated.

Values chosen (10%-M-90%) 2% - 3% - 4%

Government/institutions. As for the private sector.

Values chosen (10%-M-90%) 2% - 3% - 4%

TABLE C - 1.4

RAP INPUTS
BY APPLICATION * USER

ISTC NETWORK & REFERENCE CASE
(Penetration)

Variable	Variable Name	Private Sector			Government			Institutions		
		10%	M	90%	10%	M	90%	10%	M	90%
Initial Productivity Impact 1	$PENBAS_{1i}$	0	.05	.10	0	.075	.15	0	.075	.15
Initial Productivity Impact 2	$PENBAS_{2i}$	0	.01	.02	.01	.02	.04	.01	.02	.04
Initial Productivity Impact 3	$PENBAS_{3i}$	0	.0125	.025	.025	.0625	.075	.025	.0625	.075
Initial Productivity Impact 4	$PENBAS_{4i}$	0	.01	.015	0	.02	.03	0	.02	.03
Initial Productivity Impact 5	$PENBAS_{5i}$	0	.025	.05	0	.025	.05	0	.025	.05
% Mature Productivity Impact 1	$PENMAT_{1i}$	.10	.20	.40	.15	.30	.60	.15	.30	.60
% Mature Productivity Impact 2	$PENMAT_{2i}$	.05	.10	.20	.10	.15	.25	.10	.15	.25
% Mature Productivity Impact 3	$PENMAT_{3i}$	0	.05	.20	.025	.125	.20	.025	.125	.20
% Mature Productivity Impact 4	$PENMAT_{4i}$	.05	.10	.15	.05	.15	.20	.05	.15	.20
% Mature Productivity Impact 5	$PENMAT_{5i}$	.20	.30	.50	.20	.30	.50	.20	.30	.50

RAP INPUTS PERCENTAGE PENETRATION BY APPLICATION * USER
TABLE C - 1.4

TABLE C - 1.4 PENETRATION

Variable Name(s): $PENBAS_{1i}$ Initial regular and accepting user penetration - Application 1 (E-Mail, time-slipped communications), Private sector and institutional users.

Description: The proportion of R&D workers in both user categories who are regular users of application 1, out of those users in category i who have access to the network at time $TSTART_a$.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* E:Mail will have the highest initial penetration of all applications because of its ease of use and utility for a large number of users.

Values chosen (10%-M-90%)0 - 5% - 10%

Government/institutions. Use in this sector will be 1.5 times higher because it is more institutionalized and is an already accepted means of communication.

Values chosen (10%-M-90%)0% - 7.5% - 15%

Variable Name(s): $PENBAS_{2i}$ Initial regular and accepting user penetration - Application 2 (Virtual Terminal), Private sector and institutional users.

Description: The proportion of R&D workers in both user categories who are regular users of application 2, out of those users in category i who have access to the network at time $TSTART_a$.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Initial penetration will be low due to long period of learning the utility and function of the application. The numbers of people desiring to use facilities and software remotely is limited due to the high costs of learning how to use the particular remote systems that interest the user.

Values Chosen (10%-M-90%): 0 - 1% - 2%

Government/institutions. Penetration will be higher in this sector due to higher awareness in government and greater requirements in universities.

Values Chosen (10%-M-90%): 1% - 2% - 4%

RAP INPUTS PERCENTAGE PENETRATION BY APPLICATION * USER
TABLE C - 1.4 (CONT'D)

Variable Name(s): PENBAS$_{3i}$ Initial regular and accepting user penetration - Application 3 (File Transfers), Private sector and institutional users.

Description: The proportion of R&D workers in both user categories who are regular users of application 3, out of those users in category i who have access to the network at time TSTART$_a$.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Anticipated initial penetration was estimated at one quarter that of application 1 due to lower requirement for large file transfers (E-mail can be thought of as "small files").

Values Chosen (10%-M-90%): 0 - 1.25% - 2.5%

Government/institutions. As for private sector

Values Chosen (10%-M-90%): 2.5% - 6.25% - 7.5%

Variable Name(s): PENBAS$_{4i}$ Initial regular and accepting user penetration - Application 4 (Real-time, video conferencing), Private sector and institutional users.

Description: The proportion of R&D workers in both user categories who are regular users of application 4, out of those users in category i who have access to the network at time TSTART$_a$.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* This will be small in both sectors as only leading edge users will exploit the application.

Values Chosen (10%-M-90%): 0 - 1% - 1.5%

Government/institutions. Government use will be slightly higher due to lesser time constraints and costs constraints.

Values Chosen (10%-M-90%): 0 - 2% - 3%

RAP INPUTS PERCENTAGE PENETRATION BY APPLICATION * USER
TABLE C - 1.4 (CONT'D)

Variable Name(s): $PENBAS_{5i}$ Initial regular and accepting user penetration - Application 5 (Databases), Private sector and institutional users.

Description: The proportion of R&D workers in both user categories who are regular users of application 5, out of those users in category i who have access to the network at time $TSTART_a$.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Initial penetration will be low due to the low familiarity with current services among potential users.

Values Chosen (10%-M-90%): 0 - 2.5% - 5%

Government/institutions. As for private sector.

Values Chosen (10%-M-90%): 0% - 2.5% - 5%

Variable Name(s): $PENMAT_{1i}$ Mature regular and accepting user penetration - Application 1 (E-Mail, time-slipped communications), Private sector and institutional users.

Description: The proportion of R&D workers in both user categories who are regular users of application 1, out of those users in category i who have access to the network at time $TFIN_a$.

Module(s): R&D User Benefits.

Reasons for Values Chosen: *Private Sector.* Due to ease of learning and operation, and due to it's wide relevance to all parties, penetration will increase greatly. E-Mail will have the highest penetration of all applications.

Values Chosen (10%-M-90%): 10% - 20% - 40%

Government/institutions. Use will expand here for the same reasons while use will remain higher than in the private sector as discussed under productivity impact.

Values Chosen (10%-M-90%): 15% - 30% - 60%

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RAP INPUTS PERCENTAGE PENETRATION BY APPLICATION * USER
TABLE C - 1.4 (CONT'D)

Variable Name(s): $PENMAT_{2i}$ Mature regular and accepting user penetration - Application 2 (Virtual Terminal), Private sector and institutional users.

Description: The proportion of R&D workers in both user categories who are regular users of application 2, out of those users in category i who have access to the network at time $TFIN_a$.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector*. Penetration will increase by a factor of ten as potential for use is discovered.

Values Chosen (10%-M-90%): 5% - 10% - 20%

Government/institutions. Use will be slightly higher in government and institutions due to greater needs for facility sharing and collaboration.

Values Chosen (10%-M-90%): 10% - 15% - 25%

Variable Name(s): $PENMAT_{3i}$ Mature regular and accepting user penetration - Application 3 (File Transfers), Private sector and institutional users.

Description: The proportion of R&D workers in both user categories who are regular users of application 3, out of those users in category i who have access to the network at time $TFIN_a$.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector*. This is estimated to be one quarter that of application 1 as discussed under initial penetration.

Values Chosen (10%-M-90%): 0 - 5% - 20%

Government/institutions. As for private sector.

Values Chosen (10%-M-90%): 2.5% - 12.5% - 20%

RAP INPUTS PERCENTAGE PENETRATION BY APPLICATION * USER
TABLE C - 1.4 (CONT'D)

Variable Name(s): $PENMAT_{4i}$ Mature regular and accepting user penetration - Application 4 (Real-time, video conferencing), Private sector and institutional users.

Description: The proportion of R&D workers in both user categories who are regular users of application 4, out of those users in category i who have access to the network at time $TFIN_a$.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Penetration in this application will increase by a factor of ten due to its time-saving aspect.

Values Chosen (10%-M-90%): 5% - 10% - 15%

Government/institutions. Penetration will be slightly higher here because of higher levels of collaboration. A conservative estimate kept the lower 10% value at the same level as the private sector estimate.

Values Chosen (10%-M-90%): 5% - 15% - 20%

Variable Name(s): $PENMAT_{5i}$ Mature regular and accepting user penetration - Application 5 (Databases), Private sector and institutional users.

Description: The proportion of R&D workers in both user categories who are regular users of application 5, out of those users in category i who have access to the network at time $TFIN_a$.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Penetration should be significant in this area as user training will not be difficult and ease of operation will be high.

Values Chosen (10%-M-90%): 20% - 30% - 50%

Government/institutions. As for private sector.

Values Chosen (10%-M-90%): 20% - 30% - 50%

TABLE C - 2.1

RAP INPUT TABLE
BY R & D USER GROUPS
REFERENCE CASE

ISTC NETWORK

Variable	Variable Name	Private Sector			Government			Institutions		
		10%	M	90%	10%	M	90%	10%	M	90%
$R/D Base Expenditure (millions)	RDBASi		4640			1627			2048	
Start Year	TUPSTi		1			1			1	
Mature Year	TUPFINi	10	12	14	8	10	12	4	5	6
%Base Year Participation	UPBASi	.005	.01	.015	.08	.10	.12	.30	.50	.55
%Mature Participation	UPMATi	.15	.30	.40	.50	.60	.70	.55	.75	.80
R/D Workers Base Year	$RDUZBS_i$		55488			20083			42070	
Employee Turnover per Firm	$TURNP_i$		.10			.10			.10	

RAP INPUT TABLE BY R&D USER GROUPS - ISTC NETWORK AND THE REFERENCE CASE TABLES C - 2.1 AND C - 2.2

Introduction

These inputs deal with general network use under both the ISTC network and the reference case broken down user groups. The three divisions of R&D performers are examined with regards to start-up and maturity times, degrees of participation, workers and turnover.

Variable Name(s): $RDBAS_i$

Description: Spending on R&D by user categories in the base year.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Based on data from Statistics Canada.

Values Chosen (10%-M-90%): Fixed value $4,640 million

Government. Based on data from Statistics Canada.

Values Chosen (10%-M-90%): Fixed value $1,627 million

Institutions. Based on data from Statistics Canada.

Values Chosen (10%-M-90%): Fixed value $2,048 million

Variable Name(s): $TUPST_i$

Description: The year when network participation effectively begins for user category i.

Module(s): R&D User Benefits

Reasons for Values Chosen: *All users.* See Table C - 1.1

Values Chosen (10%-M-90%): Fixed value year 1 for ISTC network
Fixed value year 1 for the reference case

TABLE C - 2.2

RAP INPUT TABLE
BY R & D USER GROUPS

REFERENCE CASE

Variable	Variable Name	Private Sector			Government			Institutions		
		10%	M	90%	10%	M	90%	10%	M	90%
Start Year	$TUPST_i$		1			1			1	
Mature Year	$TUPFIN_i$	10	12	14	10	12	14	4	5	6
%Base Year Participation	$UPBAS_i$	.005	.01	.015	.06	.08	.10	.25	.40	.50
%Mature Participation	$UPMAT_i$	.02	.05	.08	.40	.50	.60	.55	.75	.80

RAP INPUT TABLE BY R&D USER GROUPS - ISTC NETWORK AND THE REFERENCE CASE TABLES C - 2.1 AND C - 2.2 (CONT'D)

Variable Name(s): $TUPFIN_i$

Description: The year when network participation reaches maturity for user category i.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector*. A longer uptake period due to current unfamiliarity with the system will push the maturity date ahead for private sector users.

Values Chosen (10%-M-90%): Years 10 - 12 - 14 for ISTC network
Years 10 - 12 - 14 for the reference case

Government. Government users face institutional slowness of implementation and information dissemination which means their horizon date will be as long as the private sector under the reference case. More concentrated marketing and information provision under the ISTC network will shorten the time before maturation.

Values Chosen (10%-M-90%): Years 8 - 10 - 12 for ISTC network
Years 10 - 12 - 14 for the reference case

Institutions. Institutional users are waiting for developments in networks and are ready to use the system. This is indicated by the current involvement of educational institutions in CAnet. Their time to maturity will be shorter than the other sectors.

Values Chosen (10%-M-90%): Years 4 - 5 - 6 for ISTC network
Years 4 - 5 - 6 for the reference case

RAP INPUT TABLE BY R&D USER GROUPS - ISTC NETWORK AND THE REFERENCE CASE TABLES C - 2.1 AND C - 2.2 (CONT'D)

Variable Name(s): $UPBAS_i$

Description: The proportion of R&D within category that subscribes to the network in the initial year $TUPST_i$.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* Initial use will be very low due to time constraints on most workers and low current use of existing applications.

Values Chosen (10%-M-90%): .5% - 1% - 1.5% for ISTC network
.5% - 1% - 1.5% for the reference case

Government. Use of existing applications in this sector is higher than in the private sector. Thus the initial participation is anticipated to be higher as well. It will be somewhat less under the reference case due to the less attractive lower speeds and less staff time available to promote the worth of the network to users.

Values Chosen (10%-M-90%): 8% - 10% - 12% for ISTC network
6% - 8% - 10% for the reference case

Institutions. Initial participation will be very high due to high levels of existing use and connectivity, and due to current familiarity and motivation of institutions for a research network. Differences between the two alternatives are the same as for government.

Values Chosen (10%-M-90%): 30% - 50% - 55% for ISTC network
25% - 40% - 50% for the reference case

RAP INPUT TABLE BY R&D USER GROUPS - ISTC NETWORK AND THE REFERENCE CASE TABLES C - 2.1 AND C - 2.2 (CONT'D)

Variable Name(s): UPMAT$_i$

Description: The proportion of R&D within category that subscribes to to the network when use reaches maturity, year TUPFIN$_i$.

Module(s): R&D User Benefits

Reasons for Values Chosen: *Private Sector.* The demonstration effect of network productivity gains combined with maturing of the applications, will lead to significant mature penetration. The presence of higher speed, more applications and high levels of service and technical advice under the ISTC network will lead to higher participation at maturity for the private sector. In addition, the reference case lacks the private sector mandate of the ISTC network, so that private sector access and pricing arrangements are likely to be less aggressive for user-base growth.

Values Chosen (10%-M-90%): 15% - 30% - 40% for ISTC network
2% - 5% - 8% for the reference case

Government. ISTC will have a slightly better rate of participation due to to greater speed and wider applicaitons.

Values Chosen (10%-M-90%): 50% - 60% - 70% for ISTC network
40% - 50% - 60% for the reference case

Institutions. These users will access the same applications under both networks and will be the most intensive users. Instititutions are the core motivation behind the CAnet proposal. The ISTC network is unlikely to provide significantly better mature penetration.

Values Chosen (10%-M-90%): 55% - 75% - 80% for ISTC network
55% - 75% - 80% for the reference case

RAP INPUT TABLE BY R&D USER GROUPS - ISTC NETWORK AND THE REFERENCE CASE TABLES C - 2.1 AND C - 2.2 (CONT'D)

Variable Name(s): $RDUZBS_i$

Description: The number of R&D workers in user category i in the base year.

Module(s): R&D User Costs.

Reasons for Values Chosen: *Private Sector*. Based on data provided by Statistics Canada.

Values Chosen (10%-M-90%): Fixed value 55,488

Government. Based on data provided by Statistics Canada.

Values Chosen (10%-M-90%): Fixed value 20,083

Institutions. Based on data provided by Statistics Canada.

Values Chosen (10%-M-90%): Fixed value 42,070

RAP INPUT TABLE BY R&D USER GROUPS - ISTC NETWORK AND THE REFERENCE CASE TABLES C - 2.1 AND C - 2.2 (CONT'D)

Variable Name(s): $TURNP_i$

Description: The rate of R&D worker turnover for the average firm in user category i.

Module(s): R&D Willingness to Pay.

Reasons for Values Chosen: *Private Sector.* The R&D workforce tend to be less mobile. The value was set to be roughly twice that expected of the total workforce, allowing an average of one significant career change within the R&D sector per R&D worker.

Values Chosen (10%-M-90%): Fixed value 10%

Government. Not relevant.

Values Chosen (10%-M-90%):

Institutions. Not relevant.

Values Chosen (10%-M-90%):

TABLE C - 3.1

RAP INPUTS
BY IT INDUSTRY GROUP

ISTC NETWORK

Variable	Variable Name	Service Providers			Equipment Providers		
		10%	M	90%	10%	M	90%
Elasticity of Demand	$EDIT_b$	.5	.75	1	1	2	3
Elasticity of Supply	$ESIT_b$	1	2	3	1	2	3
% Initial Sales Increase	$INCBAS_b$	.000058	.000096	.000134	.000058	.000096	.0000134
% Mature Sales Increase	$INCMAT_b$	.0058	.0096	.0134	.0058	.0096	.0134
First Year of Sales Impact	$TITST_b$		5			5	
Mature Year of Sales Impact	$TITFIN_b$	13	15	17	13	15	17

RAP INPUT TABLE BY I.T. INDUSTRY GROUPS - ISTC NETWORK
TABLE C - 3.1

Introduction

The I.T. industry is composed of two principle groups with different markets, cost factors and sales profiles. These two groups are service providers and equipment providers. These definitions have been purposely selected because they encompass a fuller range than the frequently used software/hardware classification.

Variable Name(s): $EDIT_b$ Elasticity of Demand

Description: Elasticity of Demand for IT user category b.

Module(s): I.T. Benefits and Costs

Reasons for Values Chosen: *Service providers.* Demand for services tend to depend on quality, reliablity and service differentiation more than price. The ratio of percent quantity change to percent price change is likely less than 1 (absolute value).

Values Chosen (10%-M-90%): .5 - .75 - 1

Equipment providers. For given standards, demand for equipment tends to be relatively sensitive to price. The ratio of percent quantity change to percent price change is likely to be greater than 1.

Values Chosen (10%-M-90%): 1 - 2 - 3

Variable Name(s): $ESIT_b$ Elasticity of Supply

Description: Elasticity of Supply for IT user category b.

Module(s): I.T. Benefits and Costs

Reasons for Values Chosen: *Service providers.* Elasticity of supply for both industries is relatively unknown. Fixed costs of development and production tend to be a high proportion of total costs, suggesting increasing returns to scale and a price sensitive supply. The ratio of percent change in quantity supplied to percent change in market price is likely greater than one.

Values Chosen (10%-M-90%): 1 - 2 - 3

Equipment providers. As for service providers.

Values Chosen (10%-M-90%): 1 - 2 - 3

RAP INPUT TABLE BY I.T. INDUSTRY GROUPS - ISTC NETWORK
TABLE C - 3.1 (CONT'D)

Variable Name(s): $INCBAS_b$ Percentage initial sales increase

Description: The initial percentage increase in sales from access to network test-bed possibilities for IT user group b at time $TITST_b$.

Module(s): I.T. Benefits and Costs

Reasons for Values Chosen: *Service providers.* Initial values were set two orders of magnitude lower, at 1/100 the mature levels. The first order of magnitude is to account for the need for test-bed use to mature. The second order of magnitude is to account for the need for the test-bed user base to mature.

Values Chosen (10%-M-90%): .0058% - .0096% - 0134%

Equipment providers. As for service providers

Values Chosen (10%-M-90%): .0058% - .0096% - 0134%

Variable Name(s): $INCMAT_b$ Percentage mature sales increase

Description: The mature percentage increase in sales from access to the network for It user group b at time $TITFIN_b$.

Module(s): I.T. Benefits and Costs

Reasons for Values Chosen: *Service providers.* For mature increase, used average increase in sales estimated by survey of IT firms (2.04% to 4.65%)(weighted by sales), multiplied by % of sales reported to be effected (28.88%). It was assumed that respondents who chose to answer these questions (19 out of 61) represented those who were sufficiently far sighted to have knowledge of the long run impact.

Values Chosen (10%-M-90%): .58% - .96% - 1.34%

Equipment providers. As for service providers.

Values Chosen (10%-M-90%): .58% - .96% - 1.34%

RAP INPUT TABLE BY I.T. INDUSTRY GROUPS - ISTC NETWORK
TABLE C - 3.1 (CONT'D)

Variable Name(s): $TITST_b$ First year of sales impact

Description: The year in which an impact on sales from access to the network begins for IT user group b.

Module(s): I.T. Benefits and Costs

Reasons for Values Chosen:

Service providers. An average of a four year lag between test-bed application and marketing was assumed to allow for normal product development.

Values Chosen (10%-M-90%): Fixed value year 5

Equipment providers. As above.

Values Chosen (10%-M-90%): Fixed value year 5

Variable Name(s): $TITFIN_b$ Mature year of sales impact

Description: The year in which the increase in sales from access to the network reaches a mature level for IT user group b.

Module(s): I.T. Benefits and Costs

Reasons for Values Chosen:

Service providers. It is anticipated to take roughly a decade for both test-bed use to mature and the test-bed user base to mature. The range of uncertainty chosen was plus or minus 2 years.

Values Chosen (10%-M-90%): Years 13 - 15 - 17

Equipment providers. As above.

Values Chosen (10%-M-90%): Years 13 - 15 - 17

TABLE C - 4.1

RAP INPUTS
OTHER

ISTC NETWORK

Variable	Variable Name			
		10%	M	90%
Social Benefit Multiplier	SBMULT	1	1.1	1.2
Social Discount Rate	DISCPB		.10	
Private Discount Rate	DISCPR		.1078	
User cost per person for equipment	HWCOST	181	201	221
Training cost per person	TRCOST	1325	1473	1767
Annual Turnover In R&D labour force	TURN	.04	.05	.07
Private sector equipment cost	HWCSTP	183	204	224
Public sector willingness to pay per R&D worker	PHEAD		1.3 million RDUZR (ref case)	
Recoverable portion of R&D willingness to pay	PYRPR	.5	.6	.64
Recoverable portion of IT willingness to pay	ITPAYR	.025	.05	.10
Adjustment factor matching IT Sales Growth to GNP Growth	BGRAJ		1.0	
Proportion IT Sales that is equipment	HWPROP		.53	
Years delay between R & D spending and Sales Impact	LAG	.48	4	.58
Total Sales by IT users in base year.	SALTOT		23.5 Billion	
% IT Sales Exported (as a decimal)	EXP	.34	.49	.64

RAP INPUT TABLE: OTHER INPUTS - ISTC NETWORK
TABLE C - 4.1

Introduction

Several other inputs are required to get a more accurate outcome from the RAP simulation for the ISTC network. These inputs are primarily related to I.T. and R&D user benefits and costs. Other fundamental inputs include labour statistics, market information and economic growth rates. These inputs are assumed to be equal in value for both the ISTC network and the reference case as they are generally speaking macro-economic assumption which flow from performance and trends in the Canadian economy.

Variable Name(s): SBMULT Social Benefit Multiplier

Description: Social Benefit multiplier. Represents the marginal benefit of a dollar spent on R&D. This is greater than a dollar because of known underspending on R&D.

Module(s): R&D User Benefits

Reasons for Values Chosen: The marginal productivity of a 1$ spent on R&D cannot be accurately measured. However, concensus is that it is worth more than a dollar due to known factors leading to current underspending in the Canadian economy. While comparisons may be drawn between Canada and other countries on proportions of GDP spent on R&D, the marginal value of additional spending has not been estimated. A nominal value of 10% was chosen as a mean expected undervalueing of R&D, with a confidene interval from 0% to 20%. These values convert to the multiplier values below.

Values chosen (10%-M-90%): 1 - 1.1 - 1.2

Variable Name(s): DISCPB Social Discount Rate

Description: The cost of government investment to society expressed as a real rate of interest required from investment.

Module(s): R&D User Costs

Reasons for Values Chosen: The Treasury Board of Canada recommends 10% as the social discount rate. Chosen based on Glenn P. Jenkins, Capital in Canada: Its Social and Private Performance, 1965-1974. Economic Council of Canada, 1977.

Values Chosen (10%-M-90%): Fixed value 10%

RAP INPUT TABLE: OTHER INPUTS - ISTC NETWORK
TABLE C - 4.1 (CONT'D)

Variable Name(s): DISCPR Private Discount Rate

Description: The average real cost of capital in the private sector (private sector discount rate).

Module(s): R&D Willingness to Pay

Reasons for Values Chosen: Because of corporate income taxes, the private sector rate of discount is known to be higher than the social discount rate. In order to preserve consistency in this relationship, the same source was used for average rate of return on industrial capital as the Treasury Board used for its social discount rate: Glenn P. Jenkins, Capital in Canada: Its Social and Private Performance, 1965-1974. Economic Council of Canada, 1977.

Values Chosen (10%-M-90%): Fixed value 10.78%

Variable Name(s): HWCOST User cost per person for equipment

Description: The annualized hardware cost borne by the user for each R&D worker. This cost is based on a depreciation rate sufficiently high to allow regular replacement with up-to-date technology. The discount rate employed is the public discount rate.

Module(s): R&D User Costs

Reasons for Values Chosen: Based on $500 every three years discounted using private and social discount rates respectively. This represents a presumed 3 year replacement cycle as hardware and software advances. The range of uncertainty is plus or minus 5%. The value was set as an average requirement for users which log on directly, and will require software and hardware upgrades, and local area network user requirements.

Values Chosen (10%-M-90%): 181 - 204 - 224

Variable Name(s): TRCOST Training cost per person

Description: The cost of training an R&D user to fully incorporate the network into their work-style. Includes the normal amount of time spent learning while using.

Module(s): R&D User Costs

Reasons for Values Chosen: Assumption was made that average learning time would be one week of a workers time, including loading for overhead. The uncertainty on this amount was felt to be skewed with an upper bound 20% above the central value, and a lower bound 5% below.

Values Chosen (10%-M-90%): 1325 - 1473 - 1767

RAP INPUT TABLE: OTHER INPUTS - ISTC NETWORK
TABLE C - 4.1 (CONT'D)

Variable Name(s): TURN Annual turnover in R&D labour force

Description: The overall turnover in Canada's R&D labour force.

Module(s): R&D User Costs

Reasons for Values Chosen: The 5% value is based on an expected average career life of 20 years within the R&D sector as a whole. 4% represents 25 years, and and 6% approximately 16 years.

Values Chosen (10%-M-90%): 4% - 5% - 6%

Variable Name(s): HWCSTP Private sector equipment cost per user

Description: Cost per user for hardware as perceived by individual firms. Same as HWCOST except private discount rate employed.

Module(s): R&D Willingness to Pay

Reasons for Values Chosen: Based on $500 every three years discounted using private and social discount rates respectively. This represents a presumed 3 year replacement cycle as hardware and software advances. The range of uncertainty is plus or minus 5%. The value was set as an average requirement for users which log on directly, and will require software and hardware upgrades, and local area network user requirements.

Values Chosen (10%-M-90%): 183 - 204 - 224

Variable Name(s): PHEAD Public Sector willingness to pay per R&D worker

Description: Willingness to pay expressed on a per head basis, as derived from immediate projections of educational institution demand for the reference case.

Module(s): R&D Willingness to Pay

Reasons for Values Chosen: Because public sector budgets are constrained by public policy, their willingness to pay does not necessarily reflect productivity gains. The current willingness to pay for CAnet was taken as a proxy for the willingness to pay for the ISTC network. The willingness to pay for the ISTC network is assumed to be essentially the same as CAnet due to the constrained nature of public research budgets. Preliminary estimates of user fee revenues for CAnet are approximately 1.3 million per year by year 3. To convert to a perhead willingness to pay, we divided by the expected number of R&D professionals on the system in year 3 of CAnet.

Values Chosen (10%-M-90%): $\frac{\text{1.3 million}}{\text{RDUZR (Reference Case)}}$

RAP INPUT TABLE: OTHER INPUTS - ISTC NETWORK
TABLE C - 4.1 (CONT'D)

Variable Name(s): PYRPR Recoverable portion of R&D willingness to pay

Description: Reduction in willingness to pay due to limitations in pricing mechanisms.

Module(s): R&D Willingness to Pay

Reasons for Values Chosen: The proportion of total benefit one can recover from willingness to pay depends on the elasticity of demand for Research & Development. Although little is known of the elasticity of demand for R&D, we have assumed an aggressive pricing policy in order to encourage rapid expansion of private sector use. Since revenue is maximized at a demand elasticity of negative one, the chosen elasticities reflect a less than revenue maximizing elasticity of -.9, -.75, and -.5. The implied values of proportions, assuming a linear demand curve, are given by (1/(1-.5/elasticity).

Values Chosen (10%-M-90%): 50% - 60% - 64%

Variable Name(s): ITPAYR Recoverable portion of IT willingness to pay

Description: The proportion of willingness to pay that can be recovered. It is less than one due to limitations in pricing.

Module(s): I.T. Willingness to Pay

Reasons for Values Chosen: Two factors were considere here, the imperfection of capital markets in funding R&D and the difficulty in recovering total benefits in the form of revenues. Assuming an aggressive pricing policy, the following range was assumed. It reflects the same elasticities as for R&D users in the central value, reduced by 1/12 and applying a wider range due to the uncertainty in the reduction factor.

Values Chosen (10%-M-90%): 2.5% - 5% - 10%

RAP INPUT TABLE: OTHER INPUTS - ISTC NETWORK
TABLE C - 4.1 (CONT'D)

Variable Name(s): BGRAJ Adjustment factor matching I.T. sales to GDP growth

Description: Adjustment factor matching IT sales base year to R&D growth factor base year.

Module(s): I.T. Benefits and Costs

Reasons for Values Chosen: There was no need for an adjustment. Values entered for IT sales and GDP growth were from the same year. The number one removes the impact of this variable, since it is used as a multiplier.

Values Chosen (10%-M-90%): Fixed value 1.0

Variable Name(s): HWPROP Proportion of I.T. sales that is equipment

Description: The proportion of total dollars IT sales that are equipment IT user category (the balance are service IT user category).

Module(s): I.T. Benefits and Costs

Reasons for Values Chosen: Based on proportion of IT firms identifying with the "services" sector as reported in the CANTECH data-base, plus or minus 5 percentage points.

Values Chosen (10%-M-90%): .48 - .53 - .58

RAP INPUT TABLE: OTHER INPUTS - ISTC NETWORK
TABLE C - 4.1 (CONT'D)

Variable Name(s): LAG Years delay between R&D spending and sales impact

Description: The lag in years between R&D expenditure and impact on sales.

Module(s): I.T. Benefits and Costs

Reasons for Values Chosen: Modelling constraints require that a single value be set for this number. Four was chosen as the most reasonable number, representing the average lag between R&D and impact on a product. This is a mean between an average of 3 for product research and an average of 5 for basic research.

Values Chosen (10%-M-90%): Fixed value 4 years

Variable Name(s): SALTOT Total sales by I.T. users in base year

Description: Total sales for IT users in the base year.

Module(s): I.T. Benefits and Costs

Reasons for Values Chosen: The value chosen represents the sales of IT companies as recorded from the CANTECH database.

Values Chosen (10%-M-90%): $23.5 billion

Variable Name(s): EXP

Description: % I.T. sales exported (as a decimal)

Module(s): I.T. Benefits and Costs

Reasons for Values Chosen: The survey of IT users showed that, of those who expected an impact on sales from test-bed use, 34% of sales were exported. In contrast the % exported by all respondents was 64%. Since respondents also tended to be smaller firms, it was suspected that the current proportion of export sales was not necessarily representative of the future. Both number where chosen as upper an lower indicators. The central value was chosen as a the mean between the two.

Values Chosen (10%-M-90%): 34% - 49% - 64%

RAP INPUT TABLE: OTHER INPUTS - THE REFERENCE CASE
TABLE C - 4.2 (see following page)

Variable Name(s): HWCOST User cost per person for equipment

Description: The annualized hardware cost borne by the user for each R&D worker. This cost is based on a depreciation rate sufficiently high to allow regular replacement with up-to-date technology. The discount rate employed is the public discount rate.

Module(s): R&D User Costs

Reasons for Values Chosen: Based on $500 every three years discounted using private and social discount rates respectively. This represents a presumed 3 year replacement cycle as hardware and software advances. The range of uncertainty is plus or minus 5%. The value was set as an average requirement for users which log on directly, and will require software and hardware upgrades, and local area network user requirements.

Values Chosen (10%-M-90%): 181 - 201 - 221

Variable Name(s): TRCOST Training cost per person

Description: The cost of training an R&D user to fully incorporate the network into their work-style. Includes the normal amount of time spent learning while using.

Module(s): R&D User Costs

Reasons for Values Chosen: Based on average overhead loading and salary as implied by R&D/workers. Upper range is plus 20%, lower range is -5%. The upper range is higher because of the possibility of overhead being split between R&D and other accounts.

Values Chosen (10%-M-90%): 1325 - 1473 - 1767

TABLE C - 4.2

RAP INPUTS
OTHER

REFERENCE CASE

Variable	Variable Name	Values		
		10%	M	90%
User cost per person for equipment	HWCOST	181	201	221
Training cost per person	TRCOST	1325	1473	1767
Public sector willingness to pay per R&D worker	PHEAD		1.3 million RDUZR (ref case)	
Recoverable portion of R&D willingness to pay	PYRPR	.5	.6	.64

RAP INPUT TABLE: OTHER INPUTS - THE REFERENCE CASE
TABLE C - 4.2 (CONT'D)

Variable Name(s): PHEAD Public Sector willingness to pay per R&D worker

Description: Willingness to pay expressed on a per head basis, as derived from immediate projections of educational institution demand for the reference case.

Module(s): R&D Willingness to Pay

Reasons for Values Chosen: Initial estimates of user fee revenues for CAnet are approximately 1.3 million per year by year 3. To convert to a perhead willingness to pay, we divided by the expected number of R&D professionals on the system in year 3 of CAnet.

Values Chosen (10%-M-90%): <u>1.3 million</u>
RDUZR (Reference Case)

Variable Name(s): PYRPR Recoverable portion of R&D willingness to pay

Description: Reduction in willingness to pay due to limitations in pricing mechanisms.

Module(s): R&D Willingness to Pay

Reasons for Values Chosen: The proportion of total benefit one can recover from willingness to pay depends on the elasticity of demand for Research & Development. Although little is known of the elasticity of demand for R&D, we have assumed an aggressive pricing policy in order to encourage rapid expansion of private sector use. Since revenue is maximized at a demand elasticity of negative one, the chosen elasticities reflect a less than revenue maximizing elasticity of -.9, -.75, and -.5. The implied values of proportions, assuming a linear demand curve, are given by (1/(1-.5/elasticity).

Values Chosen (10%-M-90%): 50% - 60% - 64%

TABLE C - 5.1

RAP INPUTS BY TIME

ISTC NETWORK

YEAR	GNP Growth RDGR $_t$			Network Cost NTCST		
	10%	M	90%	10%	M	90%
1		1.00			12,546,000	
2		1.02			7,722,000	
3		1.05			7,700,000	
4		1.08			12,883,000	
5		1.11			11,353,000	
6		1.15				
7		1.18				
8		1.22				
9		1.25				
10		1.29				
11		1.33				
12		1.37				
13		1.41				
14		1.48				
15		1.50				
16		1.55				
17		1.60				
18		1.65				
19		1.70				
20		1.75				

TABLE C - 5.2

RAP INPUTS BY TIME

REFERENCE CASE

YEAR	Network Cost NTCST		
	10%	M	90%
1		1.3 million	
2		1.3 million	
3		1.3 million	
4		1.3 million	
5		1.3 million	
6			
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RAP INPUTS BY TIME - ISTC NETWORK AND THE REFERENCE CASE
TABLE C - 5.1 AND C - 5.2

Variable Name(s): $RDGR_t$ GDP Growth

Description: The growth in R&D spending for year t.

Module(s): R&D User Benefits

Reasons for Values Chosen: Forecasts by Data Resources of Canada were used after consultation with Ministry of Finance, Forecasting Department.

Values Chosen (10%-M-90%): Fixed values see input table.

Variable Name(s): $NTCST_t$ Network Cost

Description: The cost of the network in year t.

Module(s): Network Cost

Reasons for Values Chosen: *ISTC Network.* Based on 5 year forecast for Multi-Access, Multi-Media backbone, (Option III). The effect of 5% inflation has been removed from years 2 through 5. Subsequent years are based on year 5 costs increasing in proportion to the number of users.

Reference Case. Current rough estimates available for CAnet estimate a cost of 1.3 million per year.

Values Chosen (10%-M-90%): See tables