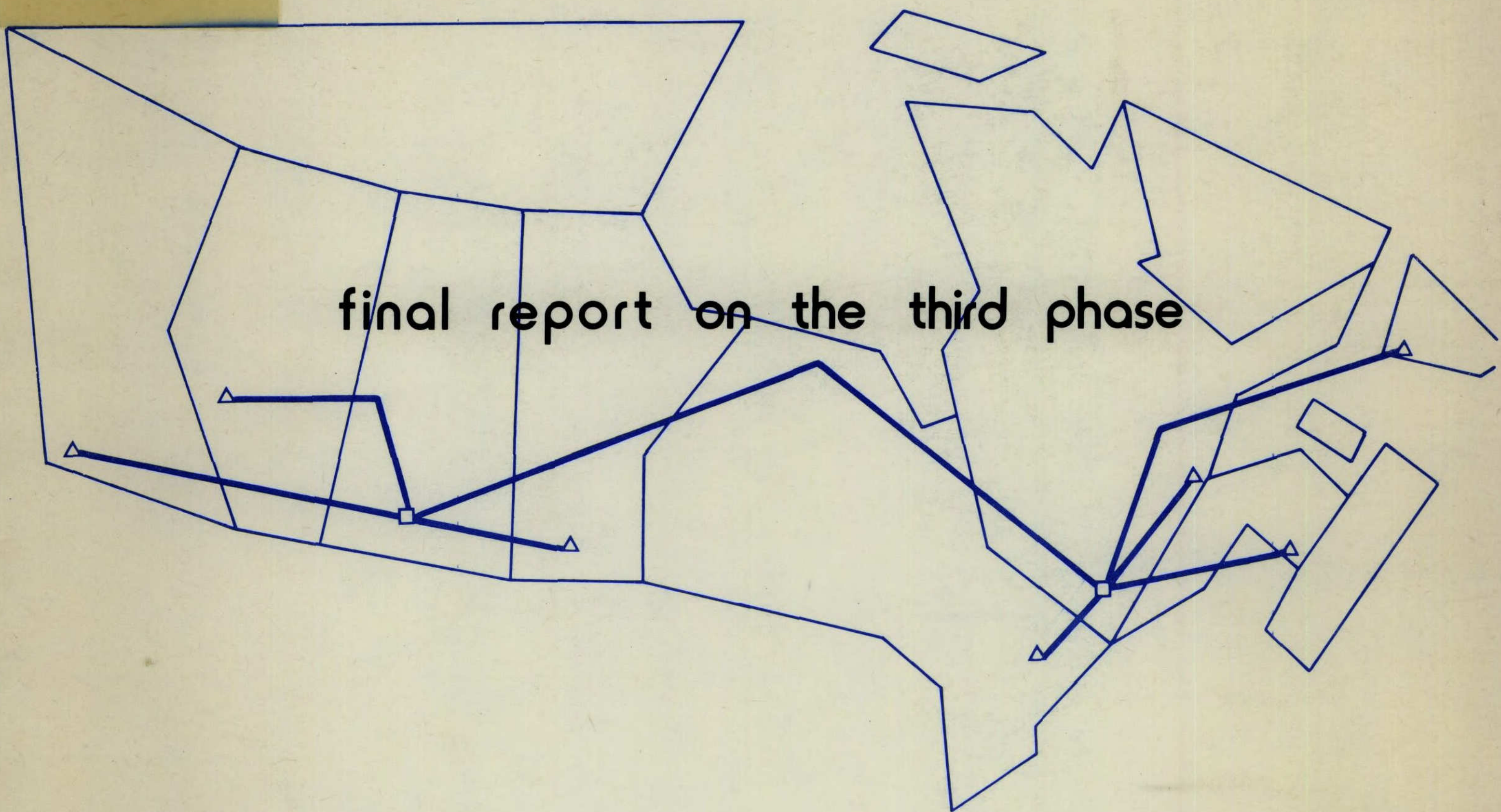
NP & PS PROJECT

final report on the third phase



PREPARED FOR AND IN COLLABORATION WITH THE

NATIONAL TELECOMMUNICATIONS BRANCH

DEPARTMENT OF COMMUNICATIONS

BY

LABORATOIRE D'ECONOMETRIE

UNIVERSITE LAVAL

AND

SORĒS INC., MONTREAL

NPPS PROJECT

NATIONAL POLICY AND PLANNING SIMULATION MODEL

(formerly known as the Inter-Regional Accounting Project)

FINAL REPORT ON PHASE III

prepared for and in collaboration with the

NATIONAL TELECOMMUNICATIONS BRANCH

DEPARTMENT OF COMMUNICATIONS

by

LE LABORATOIRE D'ECONOMETRIE

DE L'UNIVERSITE LAVAL

and

SORES INC.

Montréal

October 31st, 1975
Our ref: 1744

sores inc.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

sorès inc.

TABLE OF CONTENTS (cont'd)

APPENDICES

A. Accounting Block Flow Charts

B. Maritimes Experiment Results of Accounting Block Simulations

C. Maritimes Experiment Computer Output for Aging, Indexing and Depreciation for Mass Properties.

LIST OF FIGURES

LIST OF TABLES

FOREWORD

The main aim of the National Policy and Planning Simulation Model (NPPS Model) is to develop tools which respond to policy questions in the domain of telecommunications. Typical questions are the evaluation of costs per service, their relationships with tolls and consequently the identification and the measurement of the nature and the extent of cross-subsidization among the services. All components of the model are now operational, and have been tested in service costing experiments, but the data base needs to be updated before benchmark computations can be more representative of reality.

ABSTRACT

This Final Report on the Third Phase of the NPPS project consists of four principal chapters in addition to the Introduction, and is oriented towards reporting upon the results of a service costing experiment, using the Maritimes regional network as well as to assessing the operational treatment of the various concepts of service costing.

Following the Introduction, Chapter Two, entitled "Status of the Project", describes block by block the conceptual and software developments since the Interim Report. The main developments in the operating block have been in the implementation of an average and marginal costing capability, significant software improvements to the Circuit Allocation module, and the development of a procedure for dimensioning of the switching network, based upon the criterion of "Economic C.C.S.". The section on the Costing Block focusses on the extension of the Aging, Indexing and Depreciation algorithm to include integrated properties, and is followed by a detailed discussion of the relationship between the service costing capability of the model and the costing procedures proposed by the Cost Inquiry. In the Sharing block, developments have been limited to the implementation of program linkages which were not previously operational. Concerning the Accounting Block, documentation is presented on the simultaneous equation package, "SIR", and also on the formats of the financial statements.

The Third Chapter, "The Maritimes Region Experiment", describes a service costing exercise focussed on the Maritimes Region, undertaken in order to operationally test the conceptual and software aspects of the model, and to demonstrate the capability of producing a regional focus. The results of the simulations performed, using all blocks, are reported upon.

The fourth Chapter, "Evaluation of the Models", assesses the analytical and simulation capabilities of the model in relation both to the needs of the Department of Communications and to the objectives initially established at the beginning of the project.

The main intellectual challenges of the work reported herein have been the simultaneous presence of technical, accounting and economic variables, the determination of some trade-offs among them, the management of the model of this size and the taking into account of some of the dynamic aspects of the problem.

SOMMAIRE

Outre l'introduction, le Rapport Final sur la troisième Phase du projet NPPS comporte quatre chapitres principaux. Ce rapport est principalement axé sur les résultats d'un essai d'évaluation du coût d'un service en utilisant la région des Maritimes, ainsi que sur l'évaluation des possibilités de traitement opérationnel des différents concepts associés à l'estimation du coût d'un service.

Suite à l'introduction, le chapitre 2, présente bloc par bloc les développements conceptuels ainsi que les améliorations de système introduits depuis le Rapport Préliminaire. Pour le bloc d'opération, les principaux efforts ont porté sur l'implantation d'un algorithme permettant le calcul de coûts moyens et marginaux sur le réseau de transmission, l'amélioration du temps de calcul du modèle d'affectation et l'implantation d'un algorithme de dimensionnement du réseau de commutation basé sur le principe de l'"economic C.C.S." La généralisation des algorithmes de calcul de l'amortissement (Aging - Indexing - Depreciation) en vue de tenir compte des biens intégrés est présentée dans la section relative au bloc d'évaluation des coûts. Figure également dans cette section une comparaison approfondie entre les méthodologies et procédures respectives utilisées par la Commission d'Enquête et le modèle NPPS pour estimer le coût d'un service. En ce qui concerne le bloc de partage des revenus, le travail s'est limité à assurer l'intégration opérationnelle des programmes au reste du système. Finalement, la documentation relative au système de résolution des équations simultanées "SIR" est présentée dans la section relative au bloc comptable.

Le troisième chapitre décrit un essai d'estimation du coût d'un service spécialement axé sur la région des Maritimes, le but primordial de cet exercice étant de tester la logique et le bon fonctionnement des programmes du modèle ainsi que d'éprouver la possibilité de régionaliser les simulations. Les principaux résultats de cette expérience figurent également dans ce chapitre.

Au quatrième chapitre enfin, les capacités analytiques et les possibilités de simulation du modèle sont évaluées et comparées aux besoins du ministère des Communications ainsi qu'aux objectifs fixés en début de projet.

Le défi intellectuel du présent projet réside dans la manipulation simultanée de variables de nature technologique, comptable et économique et dans le traitement de leurs relations mutuelles, dans la manipulation d'un modèle de cette taille et aussi dans la prise en compte des aspects dynamiques du problème posé.

1. INTRODUCTION

1.1 Objectives of the Project

The Government's objectives regarding Canadian telecommunications have been identified in the Green Paper on communications policy for Canada. As a summary statement, these objectives may best be reflected by quoting from the last paragraph on page 35 of the Green Paper:

> "Economic, efficient, and adequate communications, making the best use of all available modes, are essential to the sovereignty, integrity, and defence of Canada, and for the political freedoms, social well-being, cultural development, economic prosperity, and safety of all Canadians."

It is the responsibility of the Minister of Communications to pursue national objectives. The Minister also needs to be advised and kept informed in the course of discharging his responsibilities.

The purpose of the "National Policy and Planning Simulation Model" developed by the Department of Communications is to provide for the Minister, at least in part, the necessary tools and methods for evaluating various policy options and alternatives as required by the Minister in the course of discharging his responsibilities.

One important way of evaluating the various policy options and alternatives is by examining the quantitative impacts of the scenarios under consideration through the utilization of techniques of simulation. Accordingly, the model has been designed for simulation purposes with a capability of dealing with alternatives and/or issues with respect both to the real operations of the telecommunications system and to the financial consequences for the carriers and for the system.

1.2 Context of this Report

1.2.1 Objective of this Report

This report is the Final Report on Phase III of the NPPS Project, reporting on the status of the model, the results obtained from simulations, the current capabilities of the model and future directions of the project. The final report follows the Memorandum of Understanding for Phase III, May 15th 1975 and The Interim Report on Phase III, July 31st 1975.

1.2.2 Objectives of Phase III

It is the purpose of the NPPS project to use the model operationally by applying it to the issues facing the Department in the process of making policy decisions and proposing changes in legislation, and to perfect the model to the end of executing such applications effectively and efficiently. Thus, in this phase, the main effort was to be directed towards refining and operationally applying various costing concepts for the determination of costs by service in the inter-urban telephone network.

1.2.3 Participants in the Project

The present Report represents the results of a combined effort by three groups whose formal responsabilities were spelled out in the various official documents. In practice detailed sharing of the tasks was handled by more or less informal exchanges. The tripartite team consisted of the following organizations given here with the names of the specialists involved.

The National Telecommunications Branch, Communications Canada:

Mr. J.A. Guérin
Mr. G.G. Henter
Mr. C. Lee
Mr. P. Rogers

Sorès Inc., Montreal

Mr. J. Cluchey
Mr. A. Djenandji
Miss C. King
Mr. R. Lecompte
Mr. E. Manis
Mr. J.-P. Schaack
Mr. B. Webber

Laboratoire d'économétrie de l'Université Laval

Prof. C. Autin
Prof. G. LeBlanc

As members of le Laboratoire d'économétrie, the following research assistants have contributed to the Project:

Mr. R. Huppé
Mr. G. St-Cyr

Finally, Dr. I. Young from York University, in the capacity of consultant to the Department of Communications, has contributed in the area of multi-period accounting analysis in the simultaneous equation systems.

1.3 General Description of the National Policy and Planning Simulation Model

1.3.1 Introduction

In line with the objectives set out in the Introduction, the model has been designed in a multi-faceted fashion to be capable of tying together a number of main activities. These are:

1) the structure and operations of the national telecommunications network, and the types of traffic it carries;

2) the costing processes which permit the association of various cost categories with the physical activities;

3) various alternative sharing schemes for the division of revenues generated by the services jointly provided by two or more Canadian carriers;

4) the financial and capital sourcing considerations, and the expression of the results of these activities in financial terms.

For each of these sets of activities there is a block, or module, within which the necessary computations are performed and outputs generated.

The general structuring of the model, the various blocks and their inter-relations are indicated by the Flowchart, Figure 1. This flowchart shows the four blocks just described:

- Operating block
- Costing block
- Sharing block
- Accounting block

It also contains an indication of the simulation capability, which, as can be seen, may be applied at any point in the system. In summary, then, the model is designed to process information, which is at a highly disaggregated level, from block to block, for simulation of the operating, costing, sharing and accounting activities of the national communications network. The model's "building block" structure allows simulations to be run using any one block for the examination of a particular problem, or using all blocks together as an integrated unit. This structure allows great flexibility in the variety of scenarios which may be tested and evaluated.

The following brief notes describe what the blocks contain and what they do in a rather superficial manner, to provide a preliminary overview.

1.3.2 Operating block

The Operating Block deals with the physical activities. It contains the data and algorithms pertaining to the national network, both the switching network and the transmission facilities network, the traffic processed through the network, the routing, and the tariffs applicable to the various services. There are two main outputs from the operating block:

1) The usage of facilities by elements, by service and by stream, providing an input for the costing block;

2) Presettlement gross operating revenues by stream and service, providing one component input for the revenue division process dealt with in the sharing block.

The term "element" means a switching node or a transmission link. The term "stream" refers to the traffic between a pair of origin and destination points. Service (in the present state of the model) is a category identified in the following division for intra-company or inter-company relation:

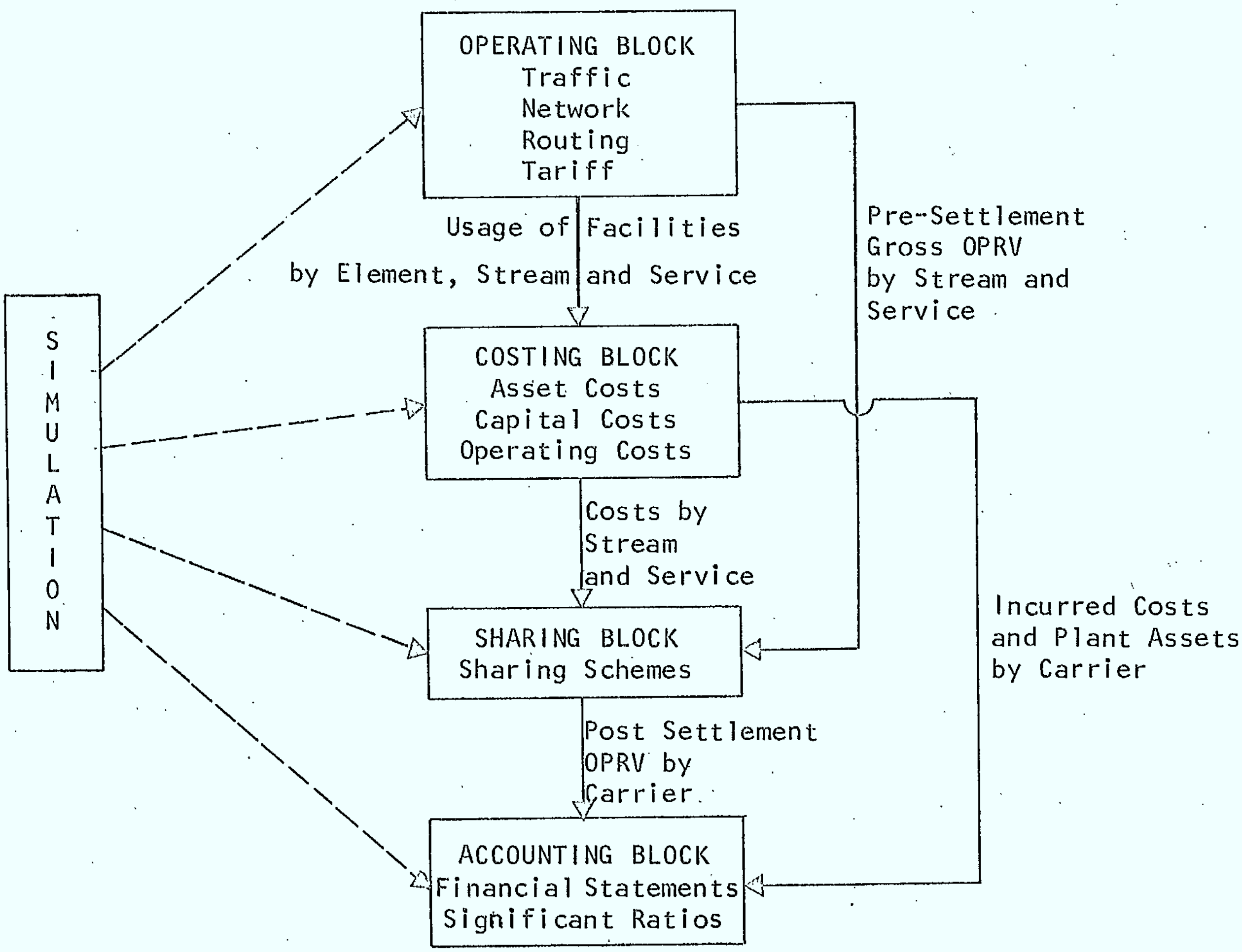
- public message toll
- TWX
- WATS
- private lines
- program transmission

It is worth noting that in addition to the specific outputs described above there are a number of other outputs available from the Operating Block. These relate to the various simulation alternatives and optimization procedures, with respect to the physical activities, which the Operating Block is capable of performing. These additional outputs may be treated as self-contained reports, evaluating different scenarios, or alternatively may be further processed through the other blocks for ultimate output from the Accounting Block reflecting the financial results or impacts of the particular alternatives considered.

It is also worth reminding the reader at this stage that this capability of producing intermediate outputs or optionally processing the information through the entire model, as indicated earlier, is similarly available in the other blocks.

FIGURE 1-1

NPPS Project
Conceptual Structure



1.3.3 Costing Block

The main function of the Costing Block is to associate costs, defined in various ways for various purposes, with the physical components (elements) of the network, and to allocate costs to various services and streams on the basis of usage. For this purpose a number of costing concepts and methodologies are employed in the Costing Block, e.g., fully distributed, incremental, reproduction, historical, etc. The main categories of costs are:

- asset costs: gross asset costs and net asset costs;
- capital costs: including depreciation, cost of capital and income taxes; and
- operating costs; such as maintenance, traffic etc.

The main outputs of the Costing Block are:

1. Costs by stream and service as the result of associating costs with the usage of facilities by elements, by service and by stream produced by the Operating Block. This output is fed into the Sharing Block.
2. The incurred costs such as depreciation and maintenance, and the plant assets by categories of plant by carrier. The plant assets by categories of plant are produced in the terms of both gross investment and net investment i.e. gross investment less accumulated depreciation. This output is fed into the Accounting Block, comprising the key components to be considered in the income statement (expenses) and the balance sheet (telephone plant assets) respectively.

1.3.4 Sharing Block

The main purpose of the Sharing Block is to consider the presettlement gross operating revenues, and the costs by stream and service in the context of the particular revenue sharing scheme which is applicable in the particular run. Out of the number of sharing schemes which may be considered not every one of the schemes require revenue and cost information by stream and service. The fine breakdown of these inputs, however, is required for some schemes as well as for other simulation purposes. The output of the Sharing Block is the post-settlement operating revenue by carrier. This provides an input for the Accounting Block (income statement) representing the results of employing a particular revenue division scheme.

1.3.5 Accounting Block

The last block in the model is the Accounting Block. It contains the accounting algorithms required to produce the financial statements, for each carrier, as the result of particular operating and/or costing and/or sharing scenarios, and as the result of the particular constraints and/or objective functions employed in the particular case. In addition to the financial statements a number of other ratios are also produced, e.g. rates of returns on various bases, debt and equity capital ratios, operating ratios etc. The outputs of the Accounting Block reflect the financial results and/or impacts consequential to the scenario of a particular simulation.

1.3.6 Simulation

From the foregoing it may be observed that the model has been structured to maintain and consider information, both exogenous and endogenous, at a level of fine disaggregation. These information elements are considered as "building blocks" which provide the capability of constructing complex modes of operating, costing, sharing, and accounting activities. By virtue of the "building block" concept and the structuring of the model in four main blocks, a very great flexibility in simulation capability has been provided. As indicated by the dotted line on the flowchart, (Figure 1). simulation scenarios may be constructed through accessing and changing information elements, constraints, objective functions, etc. in any one, in more than one or in all of the four main blocks. These scenarios and their impacts may then be evaluated by running the model end-to-end, or by examining intermediate output from any one of the blocks. This structuring of the model also provides the capability of "local optimization", i.e. in a particular block only, through employing optimization algorithms which have been built into the operating and accounting blocks.

It is important to note that although the model has been designed to deal with the national network in its entirety, it is capable of dealing with scenarios pertaining to individual carriers or regions treating them as subsets.

2. STATUS OF THE PROJECT

2.1 Overview

The major developments during the course of Phase III have been the conversion to a more powerful computer system (CSC - Infonet) and the conduct of a series of simulations related to the cost of private line service, using a generalized inter-regional network and a detailed specification of the network for the Maritimes region. The successful conduct of these simulations has operationally proved the capability of the model to address meaningful scale service costing problems.

The status of the NPPS system at the start of Phase III, and the developments envisaged in the course of the phase were discussed at length in the Memorandum of Understanding (1). The purpose of this chapter therefore, is to assess the current status of the system in terms of the activities envisaged at that time, and as updated in the Interim Report (2) with emphasis on those developments since the publication of the Interim Report.

2.2 Operating Block

2.2.1 General

The remaining linkages were completed and the models run for the Maritimes Region Experiment using a 60 node switching network. A dimensioning capability was added to the Switching Network programs, utilizing the "Economic CCS" method, and major algorithimic changes were made to the circuit allocation programs to reduce operational cost and increase simulation flexibility.

2.2.2 Traffic Module

The software for the selection of peak usage of the switching network has been modified in order to meet the new file structure. The function of this program (CMAXDE) is still unchanged and is described in the previous reports.

2.2.3 Switching Network

a) Introduction

A commonly used procedure for dimensioning a switching network was given in the "Interim Report on the Third Phase" - section

---

(1) NPPS Project Memorandum of Understanding, regarding the activities and scope of Phase III; May 1st 1975

(2) NPPS Project Interim Report on Phase III; July 31st 1975.

3.2. This procedure generally known as the "Economic C.C.S." rule has now been implemented in N.P.P.S. In this section, we propose to describe how the algorithm was applied to our problem, present some preliminary results and also give a brief outline of the ways in which this added feature could be used for the purpose of marginal costing.

b) The algorithm in N.P.P.S.

The concept behind the economic C.C.S. can be summarized as follows: traffic offered between any points A and B will be carried by the direct route between A and B as long as the marginal cost of carrying one additional C.C.S. on this route remains inferior to the corresponding cost on the alternate route. The marginal cost of carrying one additional C.C.S. on any route is given by the ratio of the number of C.C.S. carried by one additional circuit on this route and the cost to install this additional circuit.

In other words, the number of circuits to handle a given volume of traffic should be allocated between the direct route A and the alternate route B so that:

$$\frac{MV_A}{MC_A} = \frac{MV_B}{MC_B} \quad \text{or} \quad MV_A = MV_B \circ \frac{MC_A}{MC_B}$$

where MC_A = marginal investment required to add 1 circuit to the route A

MC_B = marginal investment required to add 1 circuit to the route B

MV_A = marginal volume of traffic handled on the last circuit added to route A

MV_B = marginal volume of traffic handled on the last circuit added to route B

The ratio $\frac{MC_A}{MC_B}$ (the so called "cost ratio") has a value usually

ranging between 1/1.3 to 1/1.8 as indicated in the literature The MV's obviously depend on the number of circuits as well as the traffic offered. However, it is usually assumed that the value of MV_B is 28 C.C.S. regardless of the number of circuits in so far as it exceeds a certain lower bound. This assumption appears to be valid for final groups but it is not necessarily true for high-usage groups. In our problem, for instance, traffic overflowed from one high-usage group A may be offered to another high-usage group B and, in this case, it is not unreasonable to think that MV_B could be substantially lower than 28.

In consequence, each high-usage link is dimensioned using:

- a constant cost ratio
- an MV_B of 28 when the overflow link is either a full group or a final group
- an $MV_B \leqslant 28$ when the overflow link is another high-usage group

Since final groups or full groups do not overflow, their dimensioning is based on the satisfaction of a service criterion (e.g. probability of loss smaller than a given value).

The algorithm used to arrive at dimensioning is almost identical to the one used to define the usage of a predimensioned switching network (for full details see "Interim Report on the Second Phase" section 2.2.2). The traffic carried by each high-usage link is given by a formula of the form f (n,t) where n is the number of circuits available and t the traffic offered. The same formula can be used to define the dimension n* of the link where n* is the smallest integer value for which

$$f(n^* + 1,t) - f(n^*, t) \leqslant MV_B \circ \frac{MC_A}{MC_B} = \text{a given constant}$$

Once n* has been defined, all calculations (traffic carried, traffic overflowed) are done in exactly the same manner.

For a full or final group, the probability of overflow is given by a formula of the form p (n,t). This formula can then be used to define the smallest integer n* so that $p(n^*, t) \leqslant P_o$, where P_o is a given constant.

The dimensioning feature was incorporated in the program which calculates the usage of the switching network and is given as an option to the user. Should be decide to use it, he will have to provide values for:

- the cost ratio (e.g. 1/1.5)
- the marginal traffic on final or full groups (e.g. 28)

- the marginal traffic on high-usage groups (e.g. $\leqslant$ 28)
- the maximum allowable probability of loss on final/full groups (e.g. 0.01)

c) Preliminary results

i) Run No 1

A test run was performed using the present definition of the network as used for the Maritime Region experiment, and the following parameters:

- cost ratio: 1/1.6
- marginal traffic on full/final group: 28 C.C.S.
- marginal traffic on high usage group: 20 C.C.S.
- probability of loss on final/full group: 0.01

Results obtained are shown in Table 2.1. It can be seen that in general, the circuit requirements defined by the dimensioning algorithm are smaller than the values contained in the data base. Total circuit requirements after dimensioning for the network as used for the Maritime Region experiment are 9,193, as opposed to 12,359 as contained in the permanent data base.

These differences could be attributed to two main reasons:

- o Traffic defined by the regression model is in general under-estimated (example: Totonto - Hamilton). This issue has already been raised on several occasions.
- o The dimensioning algorithm is not properly calibrated. The different parameters which were used in this test run, although remaining within a realistic range, are completely arbitrary.

This raises the question of defining parameters which are appropriate to our problem. In an earlier report ("Interim Report on 3rd Phase" - section 3.2) it was stated that cost ratio of 1/1.4 - 1/1.5 should be adequate. It was also pointed out that the value of 28 C.C.S. retained for the marginal volume of traffic is commonly used by the carriers and is adequate in so far as the number of circuits are above a certain level, which is generally the case for full or final groups. It remains to define a suitable value of the marginal volume of traffic carried on high-usage groups.

SORES inc.

TABLE 2-1

Dimensioning of Switching Network
Test Runs

Links	(a)	(b)	(c)
EDMU USA	33	0	0
WOOD USA	11	0	0
MONC KENT	3	2	2
MONC HALI	26	4	4
MONC AMHE	12	2	2
MONC CHAR	5	2	2
MONC SUMM	4	2	2
MONC TRUR	3	2	2
SAIN YARM	7	2	2
SAIN NEW	16	2	2
SAIN KENT	8	2	2
SAIN SUMM	8	2	2
REGI THUN	13	2	2
REGI LOND	13	2	2
REGI TORO	49	12	10
REGI OTTA	23	4	4
REGI HALI	5	2	2
REGI SAIN	7	2	2
MONT VANC	30	23	23
MONT CALG	35	18	17
MONT WINN	79	26	26
MONT SASK	7	4	4
MONT EDMO	25	17	19
MONT NORT	30	22	22
MONT SUDB	27	21	21
MONT LOND	70	21	21
MONT NEWC	9	2	2
MONT HALI	49	31	31
MONT ST.	39	14	14
VANC CALG	97	42	42
VANC WINN	21	20	20
VANC TORO	56	44	47
VANC OTTA	10	10	12
VANC SASK	10	6	6
VANC LOND	8	72	75*
VANC EDMO	44	42	45
CALG TORO	51	36	40
CALG WINN	43	20	19
CALG SASK	19	11	11
CALG KAML	8	4	4
CALG NELS	5	2	3
CALG CRAN	12	4	4
CALG OTTA	7	8	9
CALG LOND	8	3	4
WINN TORO	98	56	59
WINN SAIN	2	3	3
WINN OTTA	9	9	11
WINN THUN	26	16	18
WINN LOND	8	4	6
WINN EDMO	25	19	21
WINN SASK	24	11	11
TORO ST.	9	12	14
TORO QUEB	42	24	24
TORO SAIN	35	11	11
TORO SHER	16	13	13
TORO NEWC	7	2	3
TORO HALI	46	29	31
TORO EDMO	31	29	31
TORO SASK	8	10	11
TORO CORN	7	3	3
QUEB LOND	6	2	3
QUEB OTTA	26	14	14
QUEB NEWC	2	2	2
QUEB HALI	4	4	5
QUEB CORN	3	2	2
QUEB SAIN	10	3	3

Links	(a)	(b)	(c)
SAIN RIMO	6	2	2
SAIN LOND	3	2	4
SAIN OTTA	12	4	4
SAIN CORN	9	2	2
SAIN ST.	5	2	4
CORN RIMO	5	2	2
CORN HALI	5	3	4
EDMO OTTA	7	6	8
EDMO SASK	13	14	15
LOND HALI	6	4	4
SHER OTTA	8	10	10
RIMO NEWC	5	2	2
OTTA HALI	14	8	10
NEWC HALI	5	2	2
HALI ST.	9	11	13
DIGB YARM	5	0	0
SAIN DIGB	9	2	2
DIGB KENT	8	0	0
YARM SHEL	6	0	0
SHEL BRID	3	0	0
KENT BRID	3	0	0
SAIN SYDN	10	3	3
SAIN AMHE	8	2	2
SAIN CHAR	14	3	3
HALI FRED	5	2	2
AMHE TRUR	4	2	2
AMHE NEW	5	2	2
NEW TRUR	10	2	2
NEW CHAR	4	2	2
NEW SYDN	16	2	2
BATH MONC	7	2	2
SAIN BATH	10	2	2
BATH CAMP	5	2	2
MONT BATH	5	4	6
CAMP MONC	4	2	2
MONT CAMP	3	3	4
SAIN CAMP	5	2	2
NEWC EDMU	4	1	1
EDMU WOOD	4	0	0
FRED WOOD	13	2	2
WOOD EDMU	4	2	2
FRED MONC	11	2	2
NEWC FRED	10	2	2
NEWC MONC	13	2	2
SAIN HAMI	3	4	5
USA REGI	354	260	260
USA MONT	1530	1482	1481
WHIT EDMO	13	5	5
EDMO FORT	14	4	4
EDMO DAWS	25	8	8
EDMO INUV	18	2	2
EDMO GRAN	49	9	9
EDMO VEGR	50	8	8
CALG MEDE	39	20	20
CALG LETH	102	29	29
NORH SASK	47	10	10
SWIF REGI	48	10	10
MOOS REGI	53	25	25
BRAN WINN	93	21	21
KENO THUN	28	8	8
TORO HAMI	443	1447	1447
QUEB FROB	9	3	3
RIMO GOOS	5	1	1
BLAN CORN	3	0	0
SAIN MONC	79	14	14
SAIN FRED	63	10	11

Links	(a)	(b)	(c)
SAIN EDMU	27	7	7
SAIN WOOD	37	8	8
NEWC BATH	31	6	6
NEWC CAMP	21	3	3
HALI TRUR	56	12	12
HALI NEW	58	7	7
HALI CHAR	33	10	10
HALI SUMM	17	7	7
HALI AMHE	26	7	7
HALI KENT	60	6	6
HALI DIGB	19	4	4
HALI YARM	29	6	6
HALI SYDN	55	8	8
REGI VANC	120	32	31
REGI CALG	147	39	39
REGI SASK	102	26	25
REGI WINN	101	42	42
REGI MONT	86	22	22
MONT TORO	822	628	627
MONT SHER	194	207	207
MONT QUEB	393	195	195
MONT OTTA	606	354	353
MONT SAIN	119	32	32
MONT CORN	38	13	13
VANC CRAN	52	8	8
VANC NELS	57	7	7
VANC KAML	93	16	16
CALG EDMO	289	161	160
TORO NORT	150	43	43
TORO SUDB	246	91	91
TORO THUN	134	60	60
TORO LOND	509	257	256
QUEB RIMO	104	21	21
SAIN NEWC	40	5	5
SAIN HALI	78	28	28
CORN ST.	39	24	24
HALI SHEL	14	5	5
HALI BRID	47	7	7
SAIN ST.S	29	6	6

Links	(a)	(b)	(c)
VANC WHIT	6	4	4
WHIT INUV	2	0	0
WHIT FORT	6	0	0
REGI BRAN	19	8	8
WINN KENO	24	6	6
USA VANC	335	290	290
USA CALG	118	132	132
USA WINN	67	74	74
USA LOND	100	120	126
USA OTTA	20	20	20
USA THUN	8	9	10
USA TORO	1384	1541	1541
USA QUEB	11	10	10
USA SHER	8	8	8
USA SAIN	98	88	88
USA HALI	36	44	46
REGI EDMO	44	11	11
EDMO NORH	6	2	3
VEGR NORH	6	0	0
VEGR SASK	6	2	2
MEDE SWIF	6	2	2
LETH REGI	5	4	4
CALG SWIF	8	2	2
CALG MOOS	5	3	3
REGI HAMI	8	3	3
TORO FRED	4	3	4
TORO MONC	10	4	5
MONT EDMU	6	4	4
MONT FRED	6	7	7
MONT MONC	17	12	12
MONT SYDN	14	5	5
QUEB EDMU	3	2	2
RIMO CAMP	8	2	2

(a): link dimension as given in data base

(b): link dimension as obtained after dimensioning (20 c.c.s. on H.U.'s)

(c): link dimension as obtained after dimensioning (14 c.c.s. on H.U.'s)

* Error in data base.

Assume for instance that the value used for marginal traffic carried by high-usage groups was smaller than 20. Dimensioning could then yield for the same amount of traffic, a larger number of circuits on high-usage groups and consequently less overflow and less circuits on full and final groups.

ii) Run No 2

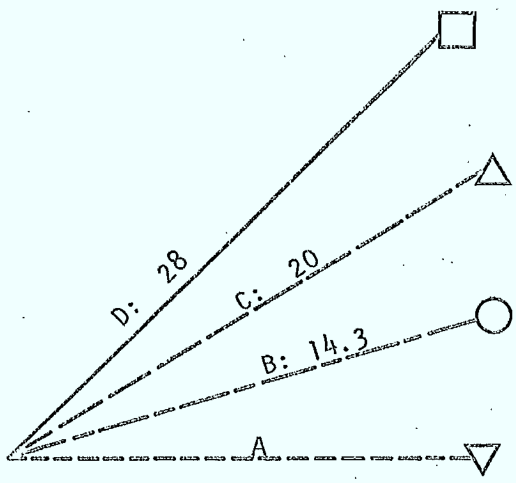
A test run was performed using 14 C.C.S. instead of 20. The differences between the two solutions are very marginal as can be seen from Table 2.1 Total circuit requirements in this case exceed the corresponding value when using 20 C.C.S. by only 55 circuits - a mere 0.5%.

iii) Analysis of Results

It appears that in our case dimensioning is not very sensitive to the parameters used. This may not remain true should traffic offered increase, and one should at first try to establish means of defining an adequate value of the marginal traffic carried by overflow high-usage groups.

FIGURE 2-1

Economic C.C.S. on Overflow H.U.'s



Let us consider the case of figure 2.1 where H.U. "A" overflows on H.U. "B" which in turn overflows on H.U. "C" which overflows on final group "D". Let us further assume a marginal traffic on "D" of 28 C.C.S. and a cost factor of 1/1.4. If the economic C.C.S. is applied to dimension C then marginal volume of traffic on C should be 28/1.4 = 20 C.C.S.; in turn marginal volume on B should be 20/1.4 or 14.3. Knowing the configuration of the network we are able to define the number of links of type B, C and consequently establish a weighted average of the marginal volume of traffic carried by any overflow H.U.

In the network used for the Maritimes experiment, there are for instance:

170 links of type C (one possible overflow)
89 links of type B (two possible overflows)
19 links of type A (three possible overflows)

This means that in the process of dimensioning, the values 20 and 14.3 should be used 89 and 19 times respectively. Should only one value be used, it should then be:

$$(20 \times 89 + 14.3 \times 19) / (89 + 19) = 19$$

or when generalized to any cost factor CF

$$28 \, (89/CF + 19/CF^2) / (89 + 19)$$

This approach, as mentioned earlier, assumes a certain level of offered traffic on each H.U. which is not the case with our present traffic data (out of 408 uni-directional links, there are at least 25% of them having an offered traffic inferior to 36 C.C.S.).

d) Use of dimensioning for incremental costing

We have seen that the allocation model was able to determine the incremental transmission cost of a service. (The term "cost" must be understood in a very broad sense here; only two concepts of costs have been implemented at present in the allocation algorithm, but it was pointed out that use of other cost concepts did not present major difficulties). The dimensioning of the network will now allow us to determine the incremental switching cost of a service. Assume a certain traffic matrix T. Dimensioning of the network immediately yields the circuit requirements to be satisfied by the allocation. Use of the allocation model yields the transmission cost of satisfying traffic T. Dimensioning of the switching network also gives the size of the switching machines required and hence the switching cost of satisfying demand T. More work is required to establish cost concepts to be used but this does not alter the "economic C.C.S." methodology.

If a service is added or removed (increased or decreased), satisfaction of demand T ± Δ T can be costed in terms of transmission and switching. Comparison of both scenario runs yields the incremental cost of providing service Δ T. The cost attached to the service can then be compared to the incremental revenues it generates and meaningful conclusions with regards to the opportunity of providing this service can be drawn.

2.2.4 Transmission Network Software Developments Implemented

a) Private line generation

A program was written to generate private line data in order to up-date the permanent private line data base into a temporary data base fitting the scenario definition. The three main options considered are:

- no private lines
- interregional private lines only, using the permanent data base
- interregional and regional private lines. Regional private line circuit requirements are generated using a fraction of the public message circuit requirements for all O-D pairs having both terminating nodes in the considered region.

b) Upper bound on objective function

It has been established, from previous runs, that the optimality phase of the allocation model (Phase 2 of CIRRES) can be rather costly. It was hence decided to determine an upper bound on the value of the objective function at optimality. This upper bound could then be used to decide upon the necessity of going into the optimality phase and how far. For example, if the upper bound on the objective is only 10% higher than its value at end of phase I (basic feasible solution) the operator may decide to skip the optimal allocation and consider the basic feasible allocation sufficient for his purposes, or else go into optimality phase but stop when he reaches "satisfactory" improvement on the objective - say within 5%.

The upper bound is calculated as follows. For the sake of simplicity assume that the objective is to maximize excess circuit-miles; a similar reasoning can be applied to the other objectives. Maximizing the number of excess circuit-miles is equivalent to minimizing the number of allocated circuit-miles since both variables are related by the following relationship:

Excess circuit-miles = Total available circuit-miles - allocated
(objective function) (constant) circuit-miles

Hence if one can find a lower bound on the allocated circuit-miles it immediately yields an upper bound on the objective function. A lower bound on the number of allocated circuit-miles can be easily obtained by assuming that all demands are satisfied through the shortest route available, irrespectively of the capacity constraints.

A shortest route algorithm being already incorporated in CIRRES, only slight modifications to the software were necessary to implement this additional feature. As far as computer time is concerned, running this additional option requires approximately 1/5 of the time necessary to reach a feasible solution.

c) Improved Basic Feasible Solution

In previous versions of the circuit allocation algorithm, the procedure was to obtain a basic feasible solution with any set of coefficients. When other coefficients were used, Phase 2 of CIRRES was applied starting from the basic feasible solution obtained before.

The idea behind the change in CIRRES is to regenerate a new basic feasible solution for each set of coefficients for which the associated value of the objective is reasonably close to the value of the upper bound, hence avoiding the need to go into optimality. Technical details follow.

Theoretically, during phase one of CIRRES a cost (or distance) of 0 should be attached to each link of the network, the only purpose of phase one being to find <u>a</u> possible route for each of the O-D's

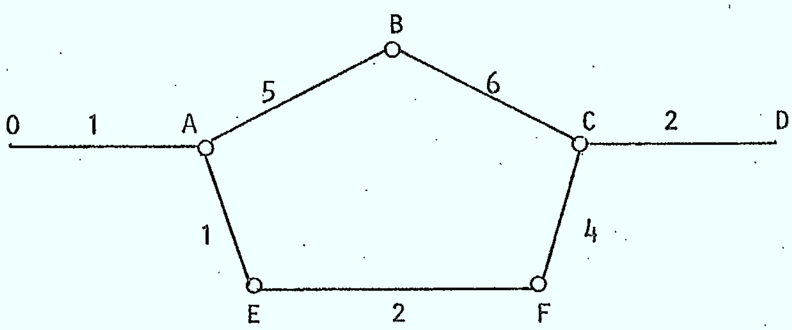
Consider the example of Figure 2-2 where a certain demand has to be allocated between O and D. Objective function coefficients are such as shown on figure 2-2 a.

Tagging each link with a zero cost in phase one would cause the route finding algorithm to loop. This algorithm, the purpose of which is to find the shortest route between O and D, will explore OABCD but also (OABC ... n x (FEABC) ... D) since these routes still have the same cost (i.e. zero) for any value of n. To avoid this problem a very small constant value (ε = .000005) had been tagged on each link. The route selected in phase one was hence OABCD since it becomes the shortest route with length = 4ε (see figure 2-2 b). This means that according to the original formulation of CIRRES, the basic feasible solution was one which minimized the number of <u>circuit-links</u> used (maximized excess circuit-links).

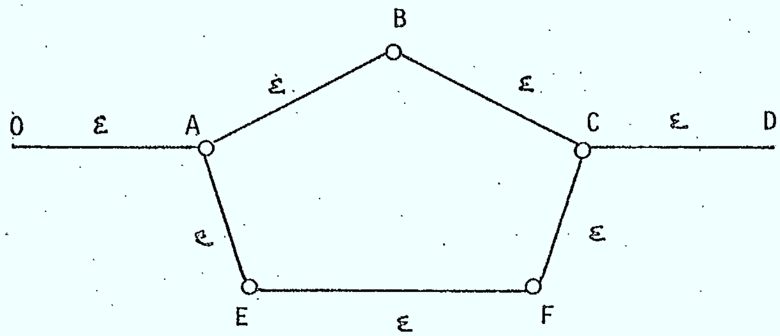
FIGURE 2-2

Theoretical example

a) Problem parameters (objective function coefficients)

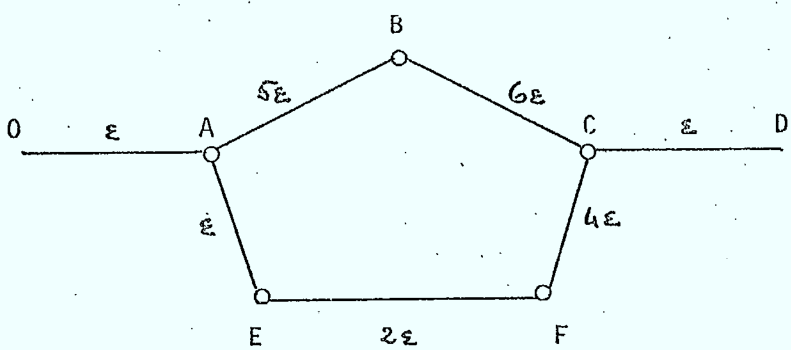


b) Original formulation



Selected route OABCD - Length 4ε

c) Revised formulation



Selected route OAEFCD - Length: 9ε

If one tags each link with a small value proportional to the actual coefficient of the objective function, (see figure 2.2 c) then the route selected is the shortest route in terms of actual costs used Consequently it leads to a basic feasible solution which is closer to the optimal allocation.

It should be noted that this is a form of the "Big M Method", as described in the literature.

In the course of the Maritimes Region Experiment, this method has yielded near-optimal solutions at a cost per run of $ 100. (batch, lowest-priority) avoiding the need to go into Phase 2 of CIRRES, at a cost which has never been precisely defined but which is known to be much higher.

However, there is no theoretical justification for supposing that this new feasible allocation will always be close enough to optimality so as to avoid the need to use Phase 2, particularly when there are a large number of saturated links.

d) Extension of Costing Algorithms

i) Cost Concepts

The necessary software modifications have been made to incorporate marginal and average costs, based upon installed capacity.

In addition, analysis of the costing algorithms indicated that certain modifications must be made to the logic used for cost definitions. These modifications, which have been implemented, are discussed below.

ii) Prorating Node Cost

According to the logic developed in the Interim Report Phase III (3.1.4.e), node costs were prorated according to the number of circuits. But the cost of a node is made up of two components:

- cost of repeaters: function of the number of channels
- cost of multiplexing (if applicable): function of the number of multiplexed circuits.

It seemed hence more logical to prorate the first component according to the number of channels and the second according to the number of multiplexed circuits.

iii) Cost Definitions

In earlier documentation, average (marginal) cost was defined as the ratio of total (variable) cost by total number of circuits. Respectively, slopes α and β of figure 2.3.

Generally speaking, however, each link carried a certain number of:

- Protection channels (circuits)
- operational channels (circuits)
- TV channels (circuits)

This suggests

o that TV costs should not be considered for defining costs for allocation purposes

o that all other costs should be charged to operational circuits rather than existing circuits.

This leads to a new definition of average and marginal costs represented graphically by α' and β' respectively on figure 2-3.

One small difficulty remains however: TV costs cannot be precisely defined for nodes and they are still accounted for (although they should not) in the present formulation. In any case the associated error can be considered rather small due to the fact that channel cost is small when compared to fixed cost.

2.3 Costing Block

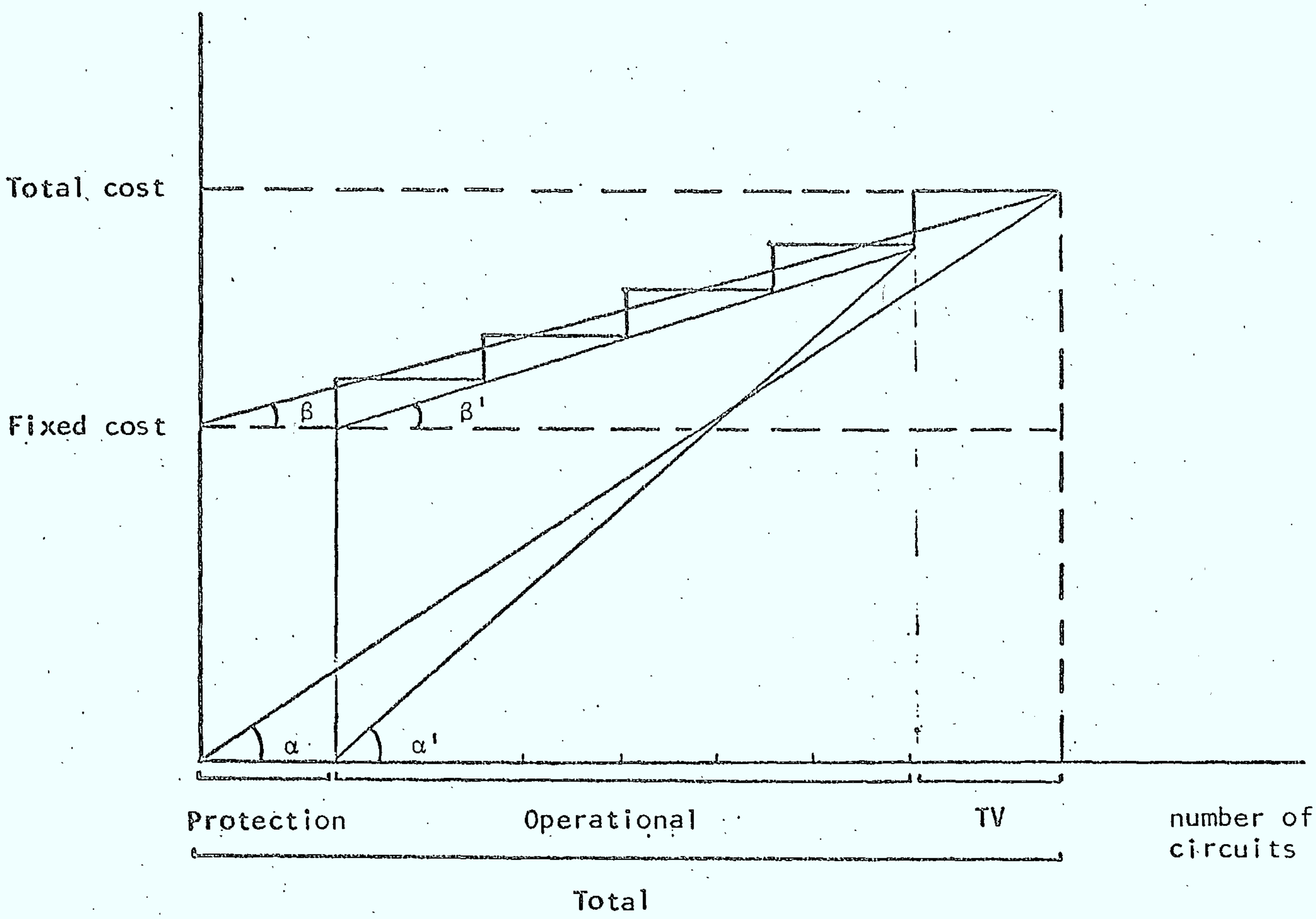
2.3.1 Asset Valuation

The modifications outlined in the Interim Report concerning (Sect.3.1.3.6) the measurement of effective capacity as a function of various multiplexing plans has not yet been implemented. The valuation procedures and data remain largely the same as before though not all the elements in Table 3.1 of the Interim Report have been implemented. For example the present software does not include echo suppressors in the valuation procedure.

In terms of implementation of concepts worked out previously, the major and most significant advance has been the development of software to calculate average and marginal costs per circuit according to the approaches outlined in the Interim Report. These values are, of course, applied to the circuit allocation program, CIRRES.

FIGURE 2-3

Definition of average and marginal per circuit costs



It should be noted though that the present software does not calculate average or incremental cost per circuit for the "ultimate structure capacity" as shown in Figure 3.1.3b of the Interim Report. The per circuit costs which are applied to the CIRRES program are based on present capacity of the system. The software and operational changes are discussed in section 2.2.4d.

2.3.2 Aging, Indexing and Depreciation: Mass Properties

a) Introduction

The previous A.I.D. formulae for mass properties have been modified to incorporate new features, such as variable growth rate and variable inflation index. The concept of age is now based on a mid-year calculation, i.e. age of plant at vintage 1 (current year addition) is 0.5 at the end of the year.

b) Initial Gross Addition

i) Using GTP at reproduction cost value

$$GA(T) = GTPR \Big/ \left(\sum_{X=1}^{T} \prod_{i=X+1}^{T} R(i) . \prod_{i=1}^{X} P(i) . SRV(y) \right) \quad ,\ldots (1)$$

where $Y = 100(X-0.5)/L$

In the case of knowing some accurate values of $V(X)'$ for the last H years, it will be interesting to investigate the possibility of introducing these values in the above formulae, which can then be written as follow:

$$GA(T) = \left(GTPR - \sum_{X=1}^{H} V(X)' \right) \Big/ \left(\sum_{X=H+1}^{T} \prod_{i=X+1}^{T} R(i) . \prod_{i=1}^{X} P(i) \; SRV(y) \right) ,\ldots (2)$$

where $Y = 100\ (X-0.5)/L$ and $\sum_{X=1}^{H} V(X)'$ is the sum of known values of vintages 1 to H.

ii) Using GTP at historical cost value (book value)

$$GA(T) = GTP \Big/ \left(\sum_{X=1}^{T} \prod_{i=X+1}^{T} R(i) . SRV(y) \right), \quad Y= 100\ (X-0.5)/L \ , \ldots (3)$$

or

$$GA(T) = \left(GTP- \sum_{X=1}^{H} V(X) \right) \Big/ \left(\sum_{X=H+1}^{T} \prod_{i=X+1}^{T} R(i) . SRV(y) \right) ,\ldots (4)$$

$y = 100\ (X-0.5)/L$

for introducing last H years known values.

Definitions

$$V(X)' = GA(X) . \prod_{i=1}^{X} P(i) . SRV(y) \qquad \ldots(5)$$

$$= GA(X+1) . R(X) . \prod_{i=1}^{X} P(i) . SRV(y)$$

$$= GA(T) . \prod_{i=X+1}^{T} R(i) . P(i) . SRV(y)$$

$$V(X) = GA(X) . SRV(y) \qquad \ldots(6)$$

$$= V(X)' / P(X)$$

$$= GA(T) . \prod_{i=X+1}^{T} R(i) . SRV(y)$$

V(X): the value of survivor of vintage, X years at historical book cost, at present.

V(X)': the current reproduction cost of V(X)

GTP: historical book cost of surviving plant.

GTPR: reproduction cost of surviving plant.

P: annual index factor.

R: annual rate of growth

L: average life

T: maximum life

T-0.5: the age of the oldest surviving plant

0.5: the age of the latest added plant

SRV(X): current percentage of surviving plant installed x years ago.

GA(X): historical value of gross addition at year X.

c) Depreciation Formulae:

i) Average Service Life Method (ASL)

$$DR = \frac{1}{L} * 100\% \qquad \ldots(7)$$

$$\bar{X} = \frac{\sum_{X=1}^{T} \left[GA(X) \circ SRV(Y) \circ (X - 0.5) \right]}{\sum_{X=1}^{T} \left[GA(X) \circ SRV(Y) \right]} \qquad \ldots(8)$$

where $Y = 100 * (X - 0.5) / L$

$X - 0.5$ = age of properties at vintage X.

Furthermore, the present life expectancy at average age $\bar{X}$ will be

$$EX = \sum_{X=\bar{X}}^{T-1} \left[(SRV(Y) + SRV(Y-1)) / 2 \right] / SRV(\bar{Y}) \qquad \ldots(9)$$

where $\bar{Y} = 100 * \bar{X}/L$

The depreciation reserve, AD, is:

$$AD = \left(1 - \frac{EX}{L} \right) * GTP * (1 - NSV) \qquad \ldots(10)$$

where NSV = net salvage value
GTP = gross telephone plant at book cost

ii) Equal Life Group Method (ELG)

The annual depreciation rate relative to all survivors at present, is:

$$DEPRAT = \frac{\sum_{X=1}^{T} \left\{ \left[TAR(Y) - TAR(Y-1) \right] \circ GA(X) \right\}}{\sum_{X=1}^{T} \left\{ \left[SRV(Y) \circ GA(X) + SRV(Y+1) \circ GA(X+1) \right] / 2 \right\}} \qquad \ldots(11)$$

where $Y = 100 * (X - 0.5)/L$

$Y+1 = 100 * (X + 0.5)/L$

The accumulated depreciation against all surviving property at present, is:

$$AD = \sum_{X=1}^{T} \left\{ \left[TAR(Y) - (1 - SRV(Y)) \right] \circ (1-NSV) \circ GA(X) \right\} \qquad \ldots(12)$$

2.3.3 Aging, Indexing and Depreciation: Integrated Properties

a) Introduction: (Aging II algorithm)

Formulae (6) to (12) of the Interim Report on the third phase (section 3.3.2 - b) have been slightly modified in order to clarify some concepts which did not meet the computer logic requirements. These modifications have no effect on the A.I.D. theory, but they were necessary for the writing of the computer program.

Before going any further, let us give some basic definitions:

X: vintage year (X = 1 refers to the present year, $X = I_o$ refers to the year of first installation)

I_o: maximum life of first installation in years (= reference or retirement year - year of first installation) (reference year is the retirement year)

T(X): Year of installation of vintage X.

S(X): Remaining life of vintage X

N(X): Maximum life of vintage X

GA(X): Gross addition at X

M: Retirement rate

AD(X): Total accumulated depreciation in dollars attributable to the vintage X at the end of reference-year, i.e. at X = 1.

ADRAT(X): Depreciation reserve ratio of year X

TAR(X): Total accumulated recoupements at year X

DEPN(X): Annual depreciation at X

DEPRAT(X): Annual depreciation rate at X

GTP(X): Gross telephone plant at year X

AVGTP(X): Average gross telephone plant at year X

The maximum life of vintage X is always given by the following formula:

$$N(X) = T(X) + S(X) \qquad \ldots(13)$$

b) Single-vintage case

All formulae for the single-vintage case are still in the previous status (Interim Report - Phase III - pp. 3-25 to 3-26)

c) Multi-vintage case

$$AD(X) = \sum_{i=1}^{T(X)} GA(i) \left\{ M(i-\tfrac{1}{2}) \ln \left[(N(i)^{(*)} - \tfrac{1}{2}) \div (i - \tfrac{1}{2}) \right] + \left[(i - \tfrac{1}{2}) \div (N(i) - \tfrac{1}{2}) \right] \left[1 - M(N(i) - \tfrac{1}{2}) \right] \right\} \qquad \ldots(14)$$

$$ADRAT(X) = \frac{AD(X)}{\sum_{i=1}^{T(X)} GA(i) \left[1 - M(i-\tfrac{1}{2}) \right]} \qquad \ldots(15)$$

$$TAR(X) = \sum_{i=1}^{T(X)} GA(i) \left\{ M(i-\tfrac{1}{2}) \left[1 + \ln \left[(N(i)-\tfrac{1}{2}) \div (i-\tfrac{1}{2}) \right] \right] + \left[(i-\tfrac{1}{2}) \div (n(i) - \tfrac{1}{2}) \right] \left[1-M(N(i) - \tfrac{1}{2}) \right] \right\} \qquad \ldots(16)$$

$$DEPN(x) = TAR(X) - TAR(X-1) \; ; \quad DEPN(1) = TAR(1) \qquad \ldots(17)$$

$$DEPRAT(X) = \frac{DEPN(X)}{\sum_{i=1}^{T(X)} GA(i) \left[1-M.i \right]} \qquad \ldots(18)$$

(*) $N(i) = S(X) + i$

2.4 Concepts of Service Costing

2.4.1 Introduction

The main purpose of this section is to describe what has been done so far in the costing of the services in the NPPS model and to tie these procedures to the costing concepts as proposed in the "Telecommunication Cost Inquiry: Costing Manual". We will proceed as follows: first, we will define, in order to provide a self-contained presentation, the various cost concepts as they appear in the Costing Manual and secondly, describe the procedures already used in the NPPS model. Finally, a comparison between the two sets of procedures will be made. We will also indicate what modifications have to be introduced in the NPPS model in order to accommodate all the proposed costing concepts, as well as how to interpret the results obtained.

2.4.2 Definitions

The Costing Manual describes four different types of costs. Before reviewing them, some conceptual distinctions must be made. In order to define a particular cost, two dimensions are taken into account: a time dimension and a variability dimension. The first one chiefly affects the investment cost, the second, the investment costs as well as the current expenses.

In the NPPS model, the main effort is directed towards allocating asset investment costs to services. This is so since having obtained asset investment allocations, the capital costs, i.e. depreciation and cost of capital, can then be readily derived. Operating costs, such as maintenance are not readily obtainable by service. Generally, however, the operating costs may be expressed as a percentage of asset costs, providing an acceptable approximation.

The following three definitions refer to the time dimension:

- <u>Embedded</u> costs refer to the recorded costs in the books of the company, irrespective of evaluation methods;

- <u>Current</u> costs refer to the cost of acquiring and/or installing units of new plant and equipment in the year during which the study is performed;

- <u>Prospective</u> costs refer to the present value of the stream of costs which will be incurred in the future for the plant and facilities needed to provide the service under study.

From the variability point of view, two distinctions are made:

- Average variable costs refer to costs which increase or decrease in response to increases or decreases in the aggregate of all services over the long run. The long run is whatever time is sufficient to permit costs changes in response to changes in service volume

- Incremental costs are the costs which are added to the system in response to the addition of a specific increment of a service, be it an entire service category or a portion of the demand for a service category. As in the previous case, they should be expressed in the long run.

Combining these time and variability concepts, we now come to the various costing concepts as described in the Costing Manual.

- Average variable embedded costs are the book capacity costs of the variable facilities and equipment which are used by each service. All facilities and equipment costs are initially assigned to services according to current usage.

- Average variable current costs are derived by multiplying the average capacity unit costs of acquiring and installing new variables plant and equipment by the number of units needed to provide the service under study. These costs reflect the current prices for the design and technology of facilities currently being installed by the carrier.

- Embedded incremental costs represent the costs which have been added to the books of the company by reason of the service having been offered in the past. They should reflect the impact of the service on all past facility additions which are still in plant.

- Prospective incremental costs represent the present value of all future additions to facilities and equipment which will be required by the continued (or new) offering of a service.

Recall that our main objective is the determination of the cost of each service provided by a carrier. The philosophy adopted to achieve it is very different in the two approaches under study. Basically speaking, in the Costing Manual, the cost (in whatever definition) of each service is determined by first of all separating the usage of all facilities among the different services and secondly by making a summation over the facilities used by the service under study. This requires that the usage be known a priori in some way or another.

2.4.3 NPPS Costing Procedures

a) Model Formulation

We now come to a brief review of the costing procedures applied in the NPPS model. We can immediately say that for a switched service, any cost is the summation of the costs in the switching network plus the costs in the transmission network.

In the following, we will restrict ourselves to the transmission costs since the switching costs are explained in the sub-section 2.2.3 d) of the present report. Moreover, the approach is the same as that used in the transmission network, i.e. the main objective is to determine certain "slopes" for the asset valuation function. Since we work with the same kinds of information for the switching machines as for the transmission elements, the same operations have to be done in order to obtain the costing concepts discussed above.

Consider the following model which will be used to compute the transmission cost of services in the NPPS model:

$$\min \sum_i (u_i - x_i^e)\ ki$$

subject to

$$Ax + x^e = u$$

$$Bx = d$$

where

- x denotes the vector of the number of circuits allocated on each chain;
- u the "capacity" on each link;
- A a matrix containing only 0 and 1 elements showing that a link can be used by more than one chain and that each chain is composed of more than one link;
- x^e is a vector of slack variables;
- B denotes a matrix, composed of 0 and 1 elements and showing the allocation of each requirement to routes (chains). The first set of constraints refers to the capacity constraints. The second set of constraints, which will be referred to as requirement constraints, show that the allocated circuits have to satisfy the vector of requirements d.

- d is the requirement vector and refers to more than one service (switched and non-switched);

- the k_i's are the costs associated with the chains of the transmission network, whichever cost concept is used.

Since the u_i^e's represent the "capacity" of the network and the x_i^e's, the excess capacity it follows that $(u_i - x_i^e)$ is the used capacity and the value of the objective function

$$\min \sum_i k_i \ (u_i - x_i^e)$$

can be interpreted as the total cost of the transmission equipment required whichever cost concept is used.

It then follows that to determine the transmission costs of each service, the algorithm must be run twice; once with all the services and once without the service under study. The incremental cost of the service considered is given by the difference between the respective values of the objective function.

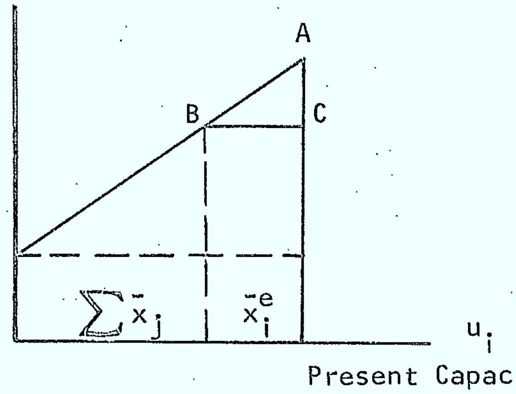
b) Graphical representation of cost coefficients and value of objective function.

It is possible to represent graphically the $k_i \ (u_i - x_i^e)$'x when the k_i's (slopes) correspond to the marginal or average variable costs, as follows.

- Figure 2-4 corresponds to the marginal cost.

FIGURE 2-4

Marginal Cost

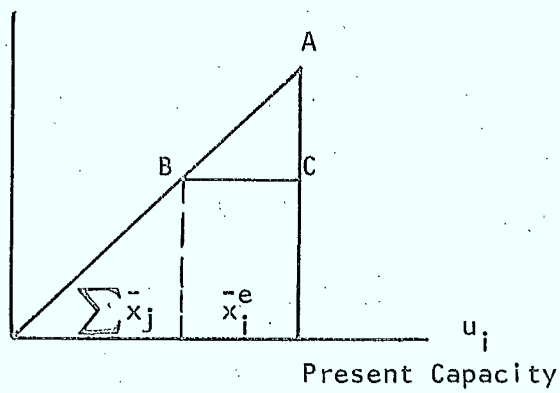


Here, the $\bar{x}_i^e$ represents the optimal unused capacity or equivalently $\sum \bar{x}_j$ is the final optimal allocation of the circuits on this particular link. Point A represents the total cost for the present capacity while B indicates the total cost of the used capacity. Consequently, the difference or the segment AC, is the total cost of the unused capacity.

o Figure 2.5 corresponds to the average variable cost.

FIGURE 2-5

Average Variable Cost



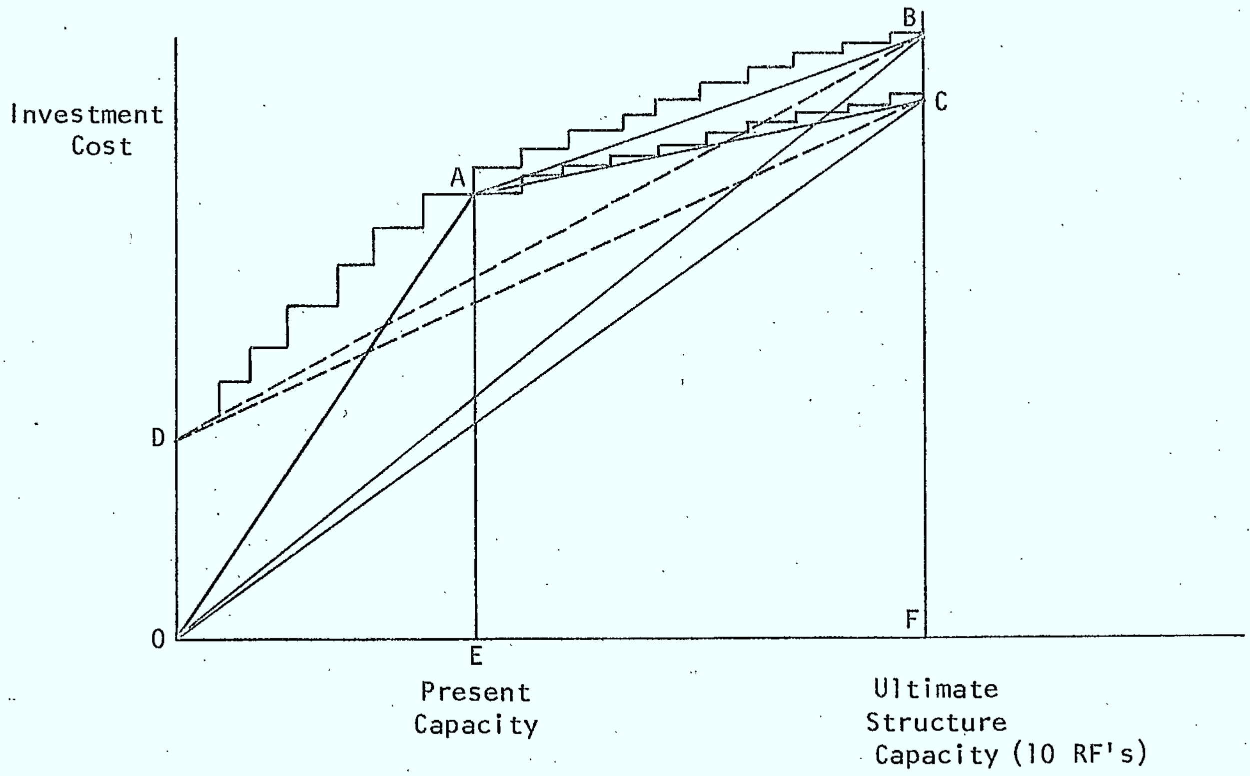
The explanations previously given, where k_i represents the marginal cost, apply in this case as well.

c) Interpretation of the k_i's

We arrive finally at the possible interpretations of the k_i's, the coefficients which appear in the objective function in the allocation model. Consider the following diagram taken from the Interim Report on the Third Phase, July 31, 1975, pages 3-11:

FIGURE 2-6

Investment Cost Interpretation



Depending on which "slope" is retained for the k_i's, we obtain the various costing concepts. For example, the slope 0A represents the current average total cost, and AB the prospective incremental cost. Of course, depending on which capacity concept is employed, the values of the u's have to be modified in consequence. Finally, we can redefine the capacity concepts in order to eliminate, if we like, channels used for protection and T.V., i.e. consider only the operational channels for the public messages. The modification is done without too much difficulty as explained in 2.2.4 of the present Report.

d) Determination of Service Cost

Once the choice of a particular cost concept is decided upon, and consequently a particular slope, the transmission cost of a service is determined as follows:

First the allocation is run, taking all the services into account and secondly, after eliminating the requirement constraints peculiar to the services under study, the difference between the values of the objective function, (i.e. the gains in terms of investment costs) will be the cost attributable to the service. Of course, prior to the second run, it is possible to revise the coefficient in order to take account of the removal of the excess capacity. This possibility of completely removing a particular service is only one characteristic of the allocation model. The model also allows the possibility of computing the cost of an increment between a particular origin-destination. In effect, suppose there is an increase in an O-D pair for a switched service: we run the algorithm in the switching network in order to obtain the new requirement vector, then in a second step, we run the allocation model again and finally we compare the values of the objective function between the initial situation and the new scenario. As may be seen, for us, the concept of a service is more general than it is in the Costing Manual, since a service can be any combination of traffic we wish to choose.

e) Dual Variable Interpretation

Finally, something can be said concerning the dual variables associated with the constraints appearing in the allocation model. It is well known that these variables measure the impact on the function of a small perturbation of the right-hand side of the constraint. In our model, the dual variables associated with the capacity constraints can be interpreted as an implicit investment cost, and those associated with the requirement constraints as implicit operating costs. Thus, if an increase in the requirement vector is such that the existing capacity has to be increased, then the cost of the increment is the sum of both costs. This interpretation of the dual variables as some costs is therefore another means of determining the costs of a service.

f) Summary

In summary, it can be noted that the NPPS Model can compute the four categories of costs, once some modifications to the software have been made, as well as others including, in particular, the current incremental costs and the avoidable costs. Remember that in the Costing Manual, since the asset functions are linear the average variable current cost is identical to the incremental current costs, which is not the same in the NPPS model since the asset functions are nonlinear.

2.4.4 Comparison with Cost Inquiry Procedure

a) Introduction

It can be noted that in the NPPS model, no a priori separation procedure, by service, has to be introduced. The only information required is the point-to-point traffic matrix and the asset valuation function of each facility. The usage of both networks is provided as the output of the Operating Block, and the costing concept employed depends on the "slope" of each of these asset valuation functions. The costing of each service is done by making a global allocation with and without a particular service and comparing the values of the objective function. In fact, we are computing costs for each service starting from the entire system and not from the cost of elements attributed to each service.

b) Trade-off of Switching and Transmission Costs

Since the NPPS model was not designed as a capacity expansion model, we take as given the hierarchy rules, etc.., and thus there is no provision for determining trade-offs between transmission and switching costs simultaneously. In other words, we take as given the switching network point-to-point matrix and circuit requirements. This is followed by the allocation of circuits in the transmission network and the derivation of costs as described above. The linkage between these networks is done by the requirements constraints.

The constraint regarding no simultaneous trade-offs between transmission and switching costs is also present in the procedures suggested in the Costing Manual; but in the NPPS model, with its simulation capabilities, it is possible to determine sequentially some trade-offs between them. That is we then obtain a different switching network and consequently the requirement constraints will be different. It then follows that the allocation of the circuits on the transmission network will be different. In this fashion, it will be possible to compare the relative costs of the switching and the transmission operations in different situations.

c) Treatment of Cost Functions

An additional difference between the Cost Inquiry and the NPPS approaches is in regards to the treatment of the cost functions, which can be seen mathematically as follows. Suppose that the investment cost function for a particular facility is of the following type (we ignore the time dimension for the moment):

$$C = \phi(q) + b$$

where b is the fixed cost, i.e. cost which has to be incurred regardless of the level of q, and $\phi(q)$ can have any particular shape.

In the Costing Manual, $b = 0$, q, expressed for example in c.c.s., is the volume for a particular service (this assumes that the separation has been made), and finally $\phi(q)$ is a linear function, so that the cost varies proportionately to the volume of the service. From the previous equation, is is then possible to redefine the variability dimension of the cost concept in the following way:

$$\text{Average Total Cost} = \phi(q)/g$$

$$\text{Average Variable Cost} = \phi(q)/g$$

Of course, since $\phi(q)$ is linear, the incremental cost (i.e. $d\phi(q)/dq$) will be equal to the average variable cost. Finally, the cost of the service under study is obtained by summing over the different facilities the appropriate costs associated with each element.

In the NPPS model, we assume the existence of some fixed costs, (i.e. $b \neq 0$), q refers to the capacity (see below for a discussion of this concept) on each particular facility, (this may be expressed in the same units as previously) and $\phi(q)$ is a step function. The main reason for retaining this particular shape is that it reflects the economies of scale peculiar to the telecommunications industry. With an appropriate linearization of $\phi(q)$ we can obtain the costing concepts discussed above.

Finally, the costing of each service is done for the transmission costs by running the algorithms twice: once with all the services and once without the service under study and comparing the values of the function.

d) Concepts of Capacity

It is appropriate to discuss the various definitions of capacity. In the Costing Manual, all costs reflect the capacity cost concept or the costs of elements at their full operational capacity. In the NPPS model, two capacity concepts are employed; the present capacity and the ultimate structure capacity. The main difference in using ultimate capacity rather than present capacity is the reduction in average cost which results, assuming that the existing technology remains unchanged. In the present model, the various cost concepts could be computed using both capacity definitions. One can also note that in the Costing Manual, as well as in the NPPS model, the cost of the excess capacity is not assigned to any specific service. However, it should also be noted that the various costs will be more sensitive to the choice of a capacity concept in the NPPS model than in the Cost Inquiry proposals since in the NPPS model, the asset cost function being nonlinear, the marginal cost is different at each capacity. This is not the case in the Cost Inquiry model.

e) Common Costs

It is well known that most plant elements are used by more than one service. Consequently, some allocation procedure has to be used in order to associate investments, as well as operating costs, with the various services. In the Costing Manual, some intermediate translators, called planning units, are developed and measured. For example, the planning units associated with local switching equipment are lines, business busy-hour CCS and busy-hour call attempts. One of the key new ideas in the NPPS model is precisely the fact that no such separation has to be done in order to compute the cost of a service. In effect, since we are allocating the circuits twice, once with both services and once with one service, the cost is then the difference between the values of the objective function, and consequently no a priori assumption has to be made on the common cost separation. However, the software so far developed permits the computation of the costs according to the current usage of the facilities.

f) Asset Valuation

We now come to a discussion concerning the asset valuation function used in the NPPS model, and its relation to the time dimension used to define the costing concepts. As it is more fully explained elsewhere in this Report, since we are using the asset valuation functions at their current value, we can compute current costs. However, two remarks can be made. The first is the fact that in the Costing Block there is an Aging, Indexing and Depreciation Algorithm. When this algorithm is utilized, (i.e. related to the asset valuation functions), it permits the computation of the book or embedded costs as well as the prospective costs. This operation necessitates some minor modifications in the software.

Secondly, when we discuss the various cost definitions it is useful to distinguish between ex post and ex ante decisions, that is the outlays that will have to be made in order to supply a service or the outlays that have already been made. Taking this distinction into account, the definition of the current costs used in the NPPS model is not the same as the one used in the Costing Manual. In fact, we can say that the one used in the NPPS model refers to the investment sequences (ex post) evaluated at their current (reproduction) value and the one used in the costing Manual refers to the very near future (ex ante).

2.4.5 Conclusions

In conclusion, it may be said that we have in the NPPS model an operational capability of deriving service costs for various cases. This capability is in addition to the other potential uses of the model. We have, from the onset, made an effort to coordinate our activities with the developments in the Cost Inquiry, and it is intended that as further progress is made in the Cost Inquiry, appropriate moidifications will be carried out in the model to maintain suitable correspondence.

2.5 Sharing Block

In the Interim Report*, it was stated that there were problems with the linkages in the sharing block. Since the publication of this report, the Sharing Block programs have been made operational, and simulations conducted using these programs.

2.6 Accounting Block

2.6.1 Simultaneous Equations Approach

The structure of the simultaneous equations approach is centred around a main program called SIR (Simulation Repeat), which does all the necessary calculations with the help of six subprograms carrying out specific tasks.

The main task of SIR is to solve a system of linear equations in the form of $Ax = 0$, which can be written

$$A_1x_1 \pm A_2x_2 = 0$$

where x_1 and x_2 represent respectively the exogenous and endogenous components of x, and A is partitioned accordingly in A_1 and A_2. In order to solve for x_2, given by

$$x_2 = - A_2^{-1} A_1 x_1$$

the first step is to specify x_1 and A. In order to do this, the main program SIR first calls the subprogram DATAGES (Data Generation System).

---

* Op. Cit.

DATAGES needs as input the 74 beads(1); it then generates 43 non-beads(2). From these beads and non-beads it generates the vector x_1 (the components of x_2 are also calculated because the program doesn't know at this stage which variables will be endogenous). This subprogram also generates some coefficients needed to construct A, plus some data needed to print out the balance sheet and funds statement.

SIR gives as output the vector x, and then asks the user if he wants to change some of its components or not. In any case, the user must specify which components are to be in x_1 and x_2 respectively. That is, which variables will be exogenous and which endogenous. Thereafter SIR calls the subprogram CONTRA (Construction of the matrix A), after which it solves the system of simultaneous equations.

The next step is the calculation of ratios, after which SIR outputs the solution of $Ax = 0$ and the ratios calculated. The balance sheet and funds statement can then be optionally output; but some components must be updated beca of the previous changes with the simulation specifications and/or the system of simultaneous equations. For example, Total Assets must be updated because Gross Telephone Plant and other variables have been changed during a simulation or after they have been recalculated by the system of simultaneous equations in which predetermined variables can alter their values.

After this operation, SIR asks the user if a simulation for the next period is wanted. If so, SIR calls for the subprogram MULTIR (Multiperiod Repeat). MULTIR needs as input the 40 Beads, plus the 17 optional Beads, plus the 30 regression Beads.* From these 87 data items it generates (with a system of appropriate equations) the values necessary to generate x_1, plus some coefficients for A, plus the data needed for the balance sheet and funds statement.

The program then re-branchches to CONTRA and proceeds according to the steps described above.

If this program block is to be used several times, the user can put into vectors the data necessary as input and keep them in computer memory. These inputs are (in order):

---

* Op. Cit. pages C-1 to C-4. Note also that one more Bead variable has been added to bring the total to 87.

(1) "Basic exogenous accounting data" variables: See Interim Report on the Third Phase (NPPS Project, pages C-9 to C-19 of Appendix C.)

(2) "Endogenous accounting data" variables: See pages C-20 and C-21 (idem).

- the 74 beads
- the numbers of variables (1 to 52) which are to be changed
- the numbers of predetermined variables
- the numbers of endogenous variables
- the number of predetermined ratios and the values of coefficients corresponding to the 52 variables (in order)

in MULTIR (simualtion for the next period):

- the 40 beads (in order)
- the 30 regression beads (in order)
- the number of the option

A complete APL printout of all programs, together with the corresponding flowcharts, is presented in the Systems Documentation Manual. However, for immediate reference, the flowcharts are also presented in the present Report, as Annex A.

2.6.2 Goal Programming Approach

In the preceeding paragraphs we have described a simultaneous linear equations approach in order to have a means of performing certain simulations in the Accounting Block. This approach is by no means the only one possible. In fact, in our previous Reports we have proposed an approach based upon the linear programming technique, called the "goal programming approach". With this technique it is possible, as with the simultaneous equation approach, to effect static as well as multi-period simulations.

The generalized goal programming approach, taking the time dimension into account, is described in the "Supplementary Report on the Second Phase", March 31, 1975, pp. 2-68, 69. Since any goal programming problem can be resolved as any standard linear programming problem, using for example the simplex method, no algorithm is proposed for solving it. This technique is already operational and the results of some simulations were reported upon in previous reports.

3. THE MARITIMES REGION EXPERIMENT

3.1 The Objectives

3.1.1 Posing the Problem

In order to test the model operationally in both its conceptual and software aspects and in order to demonstrate its capability of producing a regional focus, we established what has been called the Maritime experiment. By taking a particular region and running all the algorithms and blocks of the model, we have been able to validate the logic of the model, prove out the software, test all the various linkages in the model and compare the results to known data.

The Maritime region was chosen since it is a coherent and distinct region of the country and its telecommunications problems and issues are of current interest. Furthermore, since many of the questions of greatest importance today concern the cost of a particular telecommunications service in some "incremental" sense, the experiment centered on the cost of private line service in the Maritimes.

3.1.2 Problem Solving Objectives

The prime objective of this experiment was to demonstrate the operational capability of the model to handle a large-size problem (60 switching nodes) with a regional focus within a national context. Equally important was the objective of proving out operationally the model's ability to provide incremental cost data for a particular service, specifically private line service in the Maritimes. This was a first attempt at calculating hard figures for the cost of a particular service and represents a great advance over the usual qualitative analysis that is applied to this type of problem. The experiment also presented an opportunity to evaluate the traffic data and levels of traffic fill as well as the asset values and revenues generated by the model.

3.1.3 Computational Objectives

In terms of the development of the model in a software sense, there were several objectives. The experiment represented the first full-scale test of the software after the conversion to a new operating system. It was also an opportunity to run the model in its entirety and test all the linkages between the various blocks and modules. In some cases, it was necessary to construct additional linkages which represented major software advances. For example, the construction of the feedback loop from the costing block to the operating block was a major development since it gave us the capability to define circuit costs in a number of ways. This particular link was tested and proved operational as described in subsequent sections. In addition, many conceptual as well as software inaccuracies were detected and removed during the testing.

These corrections along with the implementation of certain unforeseen conceptual developments have allowed us to produce near-optimal or at least resonable results at significantly reduced operating cost.

3.2 Data Base

3.2.1 Switching Network

The previously used 60 node switching network with slight modifications was the basis of the network used for the Maritime Experiment. In order to include all switching centers down to level 4 in the Maritimes, three nodes had to be added: Shelburne, Bridgewater, and St-Stephen. In order to maintain the total number of nodes at 60 (the limit for software consistency), three minor nodes in Western Canada were dropped: Russel, Yorkton, and Hay River. Finally, 29 High Usage links in the Maritime Region were added. The network as it now stands for the Maritimes is displayed in the following map - Figure 3-1 and documented in Table 3-1.

3.2.2 Transmission Network

Very few changes have been made to the existing model of the transmission network. The only ones that were necessary for the experiment were the addition of seven microwave links to support the three new switching nodes (mentioned above) in the Maritimes Region. These links were all branches off existing, major microwave routes.

3.3 Analysis of the Maritimes Switching Network

3.3.1 The Network Structure

As previously discussed, the network used was that of the sixty node network. The capacity of the new links are listed in Table 3-1.

3.3.2 The Demand Module

The demand module has been run to estimate point-to-point traffic for the average peak hour.

The estimated traffic matrix has been built starting from some known traffic data*, and estimating the unknown entries by using the demand estimation model. A "peak hour to total day" ratio of 10% has been adopted.

3.3.3 The Usage Module

The usage module simulates the activity in the switching network and estimates the carried traffic on each link in terms of c.c.s. and detailed by O-D components. A typical output is given in Table 3-2.

The analysis of these results for the Maritimes experiment shows that among the final links, those whose load has decreased are in the Maritimes region. Table 3-3 illustrates this statement:

TABLE 3-3
Illustration of the Usage Module Results

Link: Campbellton - New Castle				
	% idle circuits	off. traf.	Carried traffic	% unused cap.
Basic 60 - node Maritimes 60 - node	50% 100%	41.83 0.	41.83 0.	77% 100%
Link: Bathurst - New Castle				
Basic 60 - node Maritimes 60 - node	53% 87%	78.52 1.01	78.52 1.01	75% 99.7%

---

* Source: D.O.C. Data

soros inc.

MARITIMES SWITCHING NETWORK

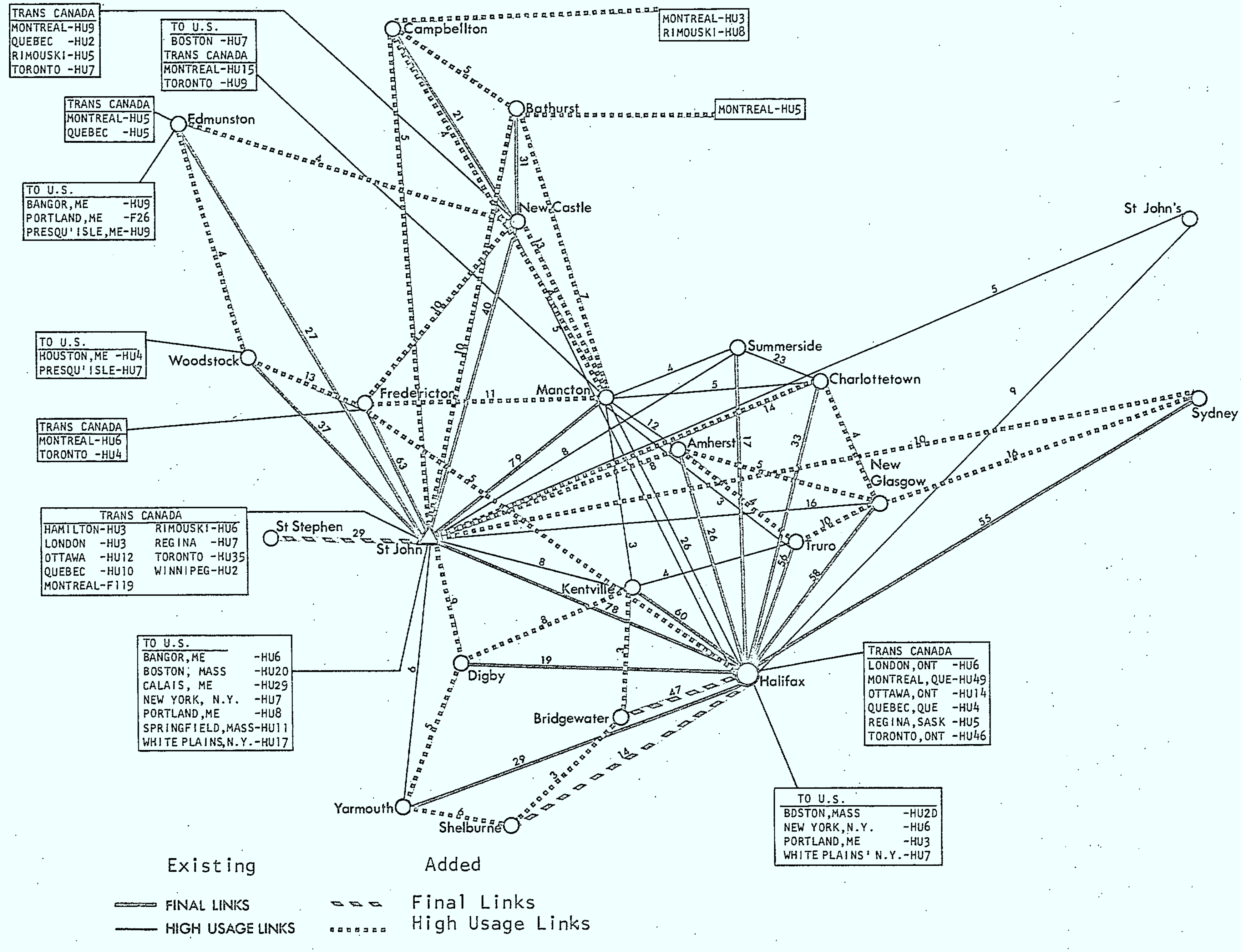


TABLE 3-1

a) Final Links Added

Link	Number of circuits
Halifax - Shelburne	14
Halifax - Bridgewater	47
St-John - St-Stephen	29

b) High Usage Links Added

Link	Number of circuits
Digby - Yarmouth	5
St-John - Digby	9
Digby - Kentville	8
Yarmouth - Shelburne	6
Shelburne - Bridgewater	3
Kentville - Bridgewater	3
St-John - Sydney	10
St-John - Amherst	8
St-John - Charlottetown	14
Halifax - Fredericton	5
Amherst - Truro	4
Amherst - New Glascow	5
New Glascow - Truro	10
New Glascow - Charlottetown	4
New Glascow - Sydney	16
Bathurst - Moncton	7
St-John - Bathurst	10
Bathurst - Campbellton	5
Montreal - Bathurst	5
Campbellton - Moncton	4
Montreal - Campbellton	3
St-John - Campbellton	5
New Castle - Edmunston	4
Edmunston - Woodstock	4
Fredericton - Woodstock	13
Fredericton - Moncton	11
New Castle - Fredericton	10
New Castle - Moncton	13
St-John - Hamilton	3

N P P S SYSTEM - SHNOUR 08/08/75???????? 14:10:06

NOTICE: -- D./P. : IS THE OVERFLOW PROBABILITY GIVEN NCIR CIRCUITS AND TOTAL OFFERED TRAFFIC.
-- CIRC. THEO. : IS THE REQUIRED NUMBER OF CIRCUITS GIVEN TOTAL OFFERED TRAFFIC AND OVERFLOW PROBABILITY(0.10 FOR HU GROUPS, 0.01 FOR FINAL & FULL).
-- TRAFFIC REQUIS : IS THE REQUIRED TRAFFIC FOR GIVEN NCIR CIRCUITS AND OVERFLOW PROBABILITY.

(A L L T R A F F I C F I G U R E S A R E I N C C S)

NU	ARETE	NCIR	TYPE	D./P.	CIRC THEO	NU COMP	COMP	TRAFFIC OFFERT	TRAFFIC ECOULE	TRAFFIC REQUIS
68	HAMI SAIN	1	HU	59.888	4					
						1	HAMI SAIN	23.00	9.22	
						2	HAMI CAMP	1.22	.47	
						3	HAMI BATH	2.12	.86	
						4	HAMI EDMU	1.91	.76	
						5	HAMI MONC	8.64	3.46	
						6	HAMI FRED	4.18	1.69	
						7	HAMI WOOD	.54	.22	
						8	HAMI AMHE	.97	.40	
						9	HAMI YARM	.97	.40	
						10	HAMI KENT	.43	.18	
						11	HAMI TRUR	1.33	.54	
						12	HAMI NEW	.97	.40	
						13	HAMI SYDN	3.53	1.40	
						14	HAMI SUMM	.86	.36	
						15	HAMI CHAR	2.12	.86	
						16	HAMI SHEL	.18	.07	
						17	HAMI BRID	.43	.18	
						18	HAMI ST.S	.32	.14	
								53.75	21.60	4.01
87	BATH SAIN	5	HU	.262	3					
						1	BATH REGI	.22	.22	
						2	BATH WINN	.61	.61	
						3	BATH LOND	1.30	1.30	
						4	BATH OTTA	4.25	4.25	
						5	BATH THUN	.32	.32	
						6	BATH TORO	7.74	7.70	
						7	BATH QUEB	5.40	5.40	
						8	BATH RIMO	.83	.83	
						9	BATH SAIN	3.96	3.92	
						10	BATH HALI	3.60	3.60	
						11	BATH CORN	.22	.22	
						12	BATH ST.	.61	.61	
						13	BATH HAMI	2.30	2.30	
						14	BATH EDMU	.36	.36	
						15	BATH FRED	.94	.94	
						16	BATH AMHE	.22	.22	
						17	BATH TRUR	.25	.25	
						18	BATH NEW	.18	.18	
						19	BATH SYDN	.50	.50	
						20	BATH SUMM	.29	.29	
						21	BATH CHAR	.54	.54	
								34.63	34.56	104.06

TABLE 3-2

Sample Output - Usage Module

SORES inc.

TABLE 3-2 (cont'd)

Sample Output - Usage Module

111	TRUR	HALI	28	FIN	.000	6					
							1	TRUR VANC	.32	.32	
							2	TRUR EDMO	.47	.47	
							3	TRUR CALG	.40	.40	
							4	TRUR WINN	.40	.40	
							5	TRUR LOND	.83	.83	
							6	TRUR OTTA	2.34	2.34	
							7	TRUR SUDH	.25	.25	
							8	TRUR THUN	.18	.18	
							9	TRUR TORO	4.72	4.72	
							10	TRUR MONT	18.76	18.76	
							11	TRUR QUEA	2.05	2.05	
							12	TRUR RIMO	.22	.22	
							13	TRUR SHER	.65	.65	
							14	TRUR SAIN	3.67	3.71	
							15	TRUR HALI	18.32	18.32	
							16	TRUR ST.	.54	.54	
							17	TRUR HAMI	1.44	1.44	
							18	TRUR BATH	.25	.25	
							19	TRUR FRED	.50	.50	
							20	TRUR KENT	.25	.25	
							21	TRUR SYDN	.76	.76	
							22	TRUR SUMM	.40	.40	
							23	TRUR CHAR	1.26	1.26	
									------	------	
									58.97	59.00	724.50
142	HALI	OTTA	7	HU	1.217	5					
							1	HALI OTTA	90.58	89.46	
							2	TRUR OTTA	2.34	2.30	
							3	SHEL OTTA	.36	.36	
							4	BRID OTTA	.79	.79	
									------	------	
									94.07	92.92	168.33
143	NEWC	HALI	2	HU	.077	1					
							1	NEWC HALI	1.26	1.26	
							2	NEWC CHAR	.18	.18	
									------	------	
									1.44	1.44	21.38
144	HALI	NEWC	2	HU	1.181	2					
							1	HALI NEWC	1.15	1.15	
							2	HALI CAMP	1.48	1.48	
							3	HALI BATH	3.38	3.35	
									------	------	
									6.01	5.98	21.38
145	HALI	ST.	4	HU	28.337	6					
							1	HALI ST.	133.52	95.69	
							2	TRUR ST.	.54	.40	
									------	------	
									134.06	96.08	73.69
146	ST.	HALI	4	HU	23.326	6					
							1	ST. HALI	111.56	85.46	
							2	ST. AMHE	.32	.25	
							3	ST. YARM	.18	.14	
							4	ST. TRUR	.50	.40	
							5	ST. NEW	.40	.32	
							6	ST. SYDN	2.66	2.02	
							7	ST. SUMM	.32	.25	
							8	ST. CHAR	.94	.72	
									------	------	
									116.89	89.57	73.69
147	OTTA	VANC	5	HU	9.345	5					
							1	OTTA CHAN	.32	.29	
							2	OTTA KAML	.76	.68	
							3	OTTA NELS	.22	.18	
							4	OTTA VANC	99.58	90.25	
									------	------	
									100.87	91.40	104.06

sores inc.

The origin and the destination of these links are generally small switching centers (level 3-4) which, in the new Maritimes network have been linked with new H.U. links. This can be explained by the fact that all primary traffic* is routed through H.U. links, then the finals get less.

More generally, most links in the Maritimes region carry less traffic components than in the previous network. Again this is explained by the addition of new H.U. links. Also, the percentage of primary traffic* has increased on the links of the new Maritimes network, and this is probably due to a decrease in the overflow probability. It is to be noted, however, that demand estimates for the region are generally low, thus accentuating the under-utilization of the network.

3.4 Circuit Allocation on the Transmission Network

3.4.1 Simulations

Within the framework of the Maritimes Region Experiment, simulations using the circuit allocation module (CIRRES) were carried out in two stages. The first, prior to implementation of software modifications yielding improved, and near optimal, basic feasible solutions, was aimed principally at proving out the operational capability of utilizing a number of cost concepts in the objective function. Thus, the software was proven for generation of circuit mile, average and marginal cost objectives.

The second stage was devoted to obtaining an estimate of the incremental cost of private line service, utilizing the upgraded software, and an objective based on average cost.

In the following paragraphs, the results for each of these two stages are presented and their significance discussed.

3.4.2 First Stage Simulations: Testing of Software

a) Basic Feasible Solution

For the experiment without private lines, the dimensions of the problems were as follows:

---

* Primary traffic on a link A-B is a load of traffic whose origin is A and whose routing priority is the link A-B.

Nodes:	172
Links:	189
Demands:	215
Constraints:	404

A feasible solution was reached after 219 iterations. The cost of obtaining this solution varied with the mode in which the system is used. The following figures however, will give an approximate range:

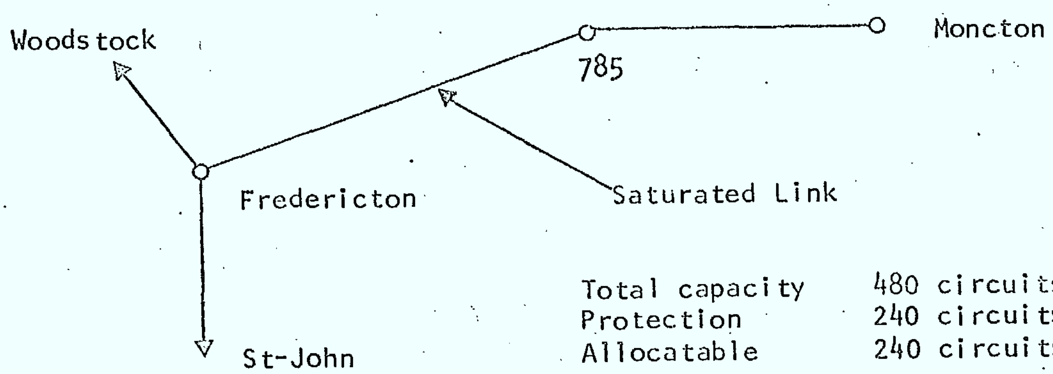
Conversational prime time: $ 400.

Batch lowest priority: $ 95.

For the experiment with private lines a first attempt using a 50% ratio for private line generation failed to yield a feasible solution. A second attempt using a 40% ratio also failed, and the results of an analysis of the allocation are illustrated in Figure 3-2.

FIGURE 3-2

Analysis of the saturated link



Total capacity	480 circuits
Protection	240 circuits
Allocatable	240 circuits

Since Moncton is a dangling node, all traffic going to and coming from Moncton has to use the link Fredericton - 785. When no private lines are considered the number of circuits required for public messages is 194 and a feasible solution can be obtained. When a 50% private line/public message ratio is used however, private lines requirements equal 87 for a grand total of 87 + 194 = 281 circuits, hence saturation. This difficulty could be avoided by the implementation of software procedures for identifying evident cases of saturation.

Subsequently, a ratio of 25% was used and a feasible allocation was reached. The detailed allocations for both solutions - with and without private lines - on the previously saturated link are shown in Table 3-4, columns 2 & 3 of which are derived from the output presented in Table 3-5. All saturated links for both allocations are also presented in this table.

Dimensions of this problem were as follows:

Nodes:	172
Links:	189
Demands:	244
Constraints:	433

The number of iterations required was 253 and the corresponding computer cost varies between $ 550. for conversational, prime time and $ 130. for batch processing lowest priority.

b) Optimality Phase

No attempts were made to go into optimality phase. However, the upperbound algorithm previously described was applied to all three objective functions and yielded interesting results.

o Objective Function 1: Circuit Miles

Details of the available, allocated and excess circuit miles for both hopotheses are given in Table 3-6. It can be seen that after basic feasible allocations, total circuit-mileage attributable to private lines is 1,462,298. Most interesting is the fact that optimal allocation could only improve the objective function by at most 2% and 4% over basic feasible allocation. By combining both results, it can be shown that incremental circuit-mileage attributable to private lines is larger than 805,235 miles and smaller than 1,806,298 when all demands are optimally allocated.

- Objective Functions 2 and 3: Average and Marginal Costs

  The software used in the first stage of the experiment yielded inadequate results but they are none the less interesting so as to underscore the significance of the improvements which result from the subsequent software modifications (i.e. improved basic feasible solution). Main results concerning basic feasible solutions and upperbound algorithms are displayed in Table 3-7. It will be noted that the incremental cost of private lines after basic feasible allocation is:

  $ 44,583,160 if average cost is used

  $ 25,095,626 if marginal cost is used

  These results, however, cannot be considered satisfactory. The upper bound algorithm shows that the improvement brought to the objective function by the optimality phase could be anywhere between 0 and 40% to 70% according to the scenario used. The corresponding ranges for the incremental cost of private lines given below are far too large to yield any significant conclusions.

  Average cost: $ 0 ≤ Incremental cost ≤ $ 104,124,580

  Marginal cost: $ 0 ≤ Incremental cost ≤ $ 64,813,920

In conclusion, it can be said that the basic feasible allocations obtained could be considered satisfactory within the context of this experiment for the purpose of incremental costing when the allocation objective is to maximize excess circuit-miles. For both alternate objectives (average cost and marginal cost) however, it is believed that no significant conclusions can be drawn without exploring the optimality phase of the allocation model.

TABLE 3-4

Analysis of saturated links
Basic feasible solution

a) Link Fredericton - 785: 240 circuits available circuits requirements

O.D. Pairs	Without P.L. Public Messages	P.L. 25%				
		Public Messages	Private lines		Total	
			25%	50%	25%	50%
Moncton - Toronto	10	10	0	0	10	10
Moncton - Montreal	17	17	0	0	17	17
Moncton - Kentville	3	3	1	2	4	5
Moncton - Halifax	26	26	7	13	33	39
Moncton - Amherst	12	12	3	6	15	18
Moncton - Charlottetown	5	5	1	3	6	8
Moncton - Summerside	4	4	1	2	5	6
Moncton - Truro	3	3	1	2	4	5
Moncton - Bathurst	7	7	2	4	9	11
Moncton - Campbelton	4	4	1	2	5	6
Moncton - Fredericton	11	11	3	6	14	17
Moncton - New Castle	13	13	3	7	16	20
Moncton - Saint-John	79	79	20	40	99	119
Total	194	194	43	87	237	281

b) List of saturated links for both basic feasible solutions.

Without private lines

594 - 593
598 - 571
498 - 491
Montreal - Quebec

With private lines

same as "without private lines"
plus: Lethbridge - Medecine Hat

492 - Winnipeg
496 - 492
895 - Ardoize
571 - 570

TABLE 3-5

Sample of Output
(25% Private Lines)

```
152 FRED- 785   CAPACITY:  2 2-WAY CH (  240 CPC)=  480. CIRCUITS
                DISTANCE:  13. MILES
                CIR-MILES:   3120.
         USES: -TELEVISION:    2 1-WAY CHANNELS
                               0 2-WAY CHANNELS
                               2 SIGNALS
               -PROTECTION:    1 CHANNELS
               -PUBLIC AND PRIVATE LINE SERVICE BREAKDOWN(CIRCUITS)
                TORO-MONC    10.0 PM       0.   PL
                MONT-MONC    17.0 PM       0.   PL
                MONC-KENT     3.0 PM       1.0  PL
                MONC-HALI    26.0 PM       7.0  PL
                MONC-AMHE    12.0 PM       3.0  PL
                MONC-CHAR     5.0 PM       1.0  PL
                MONC-SUMM     4.0 PM       1.0  PL
                MONC-TRUR     3.0 PM       1.0  PL
                BATH-MONC     7.0 PM       2.0  PL
                CAMP-MONC     4.0 PM       1.0  PL
                FRED-MONC    11.0 PM       3.0  PL
                NEWC-MONC    13.0 PM       3.0  PL
                SAIN-MONC    79.0 PM      20.0  PL
                TOTAL:      194.0         43.0
               -IDLE:         3.0
      % USES:   TELEVISION:        0.
                PUBLIC MESSAGE:   40.4
                PRIVATE LINE:      9.0
                PROTECTION:       50.0
                IDLE:               .6
```

TABLE 3-6

Allocation using circuit miles

	No. P.L.	P.L generated using 25%	Increment △
Total available c-m.	25,672,980	25,672,980	-
c-m used in protection and TV	4,203,780	4,203,780	-
c-m available	21,469,200	21,469,200	-
Basic feasible solution			
c-m used for P.M.	4,157,675	4,623,754	466,079
c-m used for P.L.	-	996,219	996,219
c-m used	4,157,675	5,619,973	1,462,298
Excess capacity (c.m)	17,311,525	15,849,227	805,235 ⩽ △ ⩽ 1,806,298
Upperbound (c.m)	17,655,525	16,506,290	
Upperbound to relative improvement brought by phase II	2.0%	4.1%	

TABLE 3-7

Allocation using average and marginal costs

	Average cost ($)			Marginal cost ($)		
	Without private lines	With private lines	Difference Δ	Without private lines	With private lines	Difference Δ
Total available (excluding TV and protection)	268,464,810	268,464,810	-	178,908,490	178,908,490	-
Total excess at end of basic feasible solution	154,851,250	110,268,090	44,583,160	105,526,030	80,430,404	25,095,626
Upperbound on total excess	214,392,670	199,058,170	$0 \leq \Delta \leq$	145,244,320	135,859,850	$0 \leq \Delta \leq$
Maximum possible improvement at optimality	38.5%	80%	104,124,580	37.6%	68.9%	64,813,920

3.4.3 Second Stage Simulations: Incremental Costing

a) General Results of Allocation Using Average Cost

After implementation of a certain number of changes as discussed in section 2.2.4 (i.e. improved B.F.S. and new cost definitions), CIRRES was run with and without private lines using average cost coefficients. The results obtained are shown in Table 3-8. Comparison of both runs shows that after basic feasible allocation, the incremental cost of private lines is estimated at $ 30 millions. Using upperbounds allows us to fix a range on the incremental cost after optimal allocation. This range goes from $ 25 to 33 millions. Detailed calculations on how this range is attained are shown in Figure 3-3.

No attempts were made to reach an optimum from these B.F.S.'s. An earlier attempt starting from circuit miles allocation showed that after 80 iterations the objective function had only progressed by 3% and was still 38% away from upperbound as detailed in Table 3-9. The test was not carried further.

b) Analysis of Differences in Allocation

Since the output of both allocations is rather exhaustive, we shall concentrate on a limited number of results only, namely 2 O-D's (Table 3-10).

From Table 3-10 it can be seen that, for example (a), circuit-mile allocation costs (6,617 - 4,658) x 49 = $95,991 more than average-cost allocation and, vice-versa, average cost allocation uses 1,666 more circuit miles than circuit-mile allocation. The corresponding figures for example (b) are $516,240 and 2,880 circuit-miles.

One can also notice that average costs of links are far from being proportional to the mileage. As a matter of fact, a regression performed between mileage and average cost on 20 randomly selected links yielded a very poor R^2 of .10.

Table 3-11 gives an extreme example of this lack of relationship where 2 links having distances of 8 and 193 miles have average costs of $3,873 and $2,828 respectively. Detailed calculations show that channel size and multiplexing cost are responsible for most of this difference.

At this stage, it should be remembered that a certain number of crude assumptions remain in the system, among them:

- multiplexing capacity of a junction or terminal node is equal to the operational capacity of the largest adjoining link (example 4(a): 183 = 1,200, DAWS = 300)

- cost of the node is prorated on adjoining links partly according to the number of channels, partly according to the number of circuits.

In conclusion, we believe that some further attention should be given to the problem of cost definition.

TABLE 3-8

Results of CIRRES with average cost coefficients

	Without private lines $ Millions	With private lines $ Millions
Total transmission assets in network (excluding TV)	423.9	423.9
Upper bound on excess transmission equipment	334.1	309.1
Excess obtained at end of B.F.S.	332.1	301.1
Margin between Upperbound and BFS	.6%	2.6%
Incremental investment required by private lines	$25.0 \leq \Delta \sim 31.0 \leq 33.0$	

TABLE 3-9

Phase 2 test run without private lines

	$ Millions				Approximate Computer cost (1) $
Value of upper bound	334.1	43%			45
Value at iteration 219 (B.F.S.)	233.6		38%		105
Value at iteration 297	241.3			1%	65
Value at iteration 220 (improved B.F.S.)	332.1				150 (2)

(1) Batch low priority
(2) Includes upperbound calculations

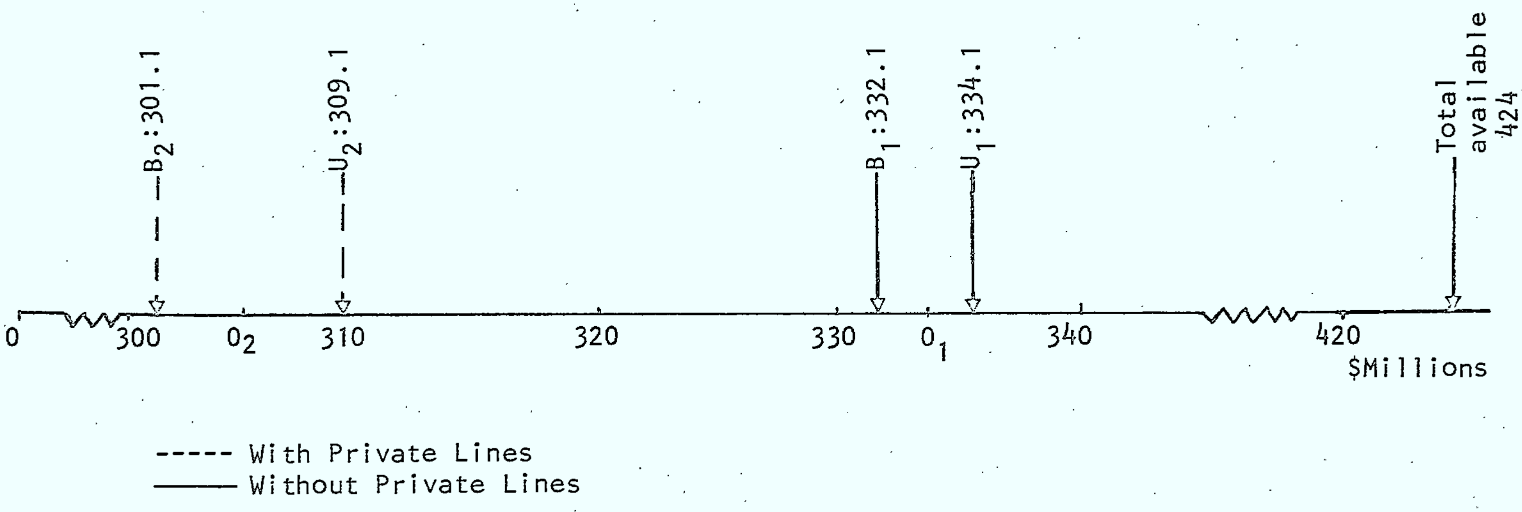


FIGURE 3-3

Range on Incremental Cost of Private Lines

Since the optimum has to lie between the upperbound and the basic feasible solution.

(1) $B_1 \leq O_1 \leq U_1$

(2) $B_2 \leq O_2 \leq U_2$

(3) $B_1 - U_2 \leq O_1 - O_2 \leq U_1 - B_2$

or $23.0 \leq \Delta \leq 33.0$

Since the difference between optimum and upperbound represents the penalty attached to saturations and since there are obviously more saturations when private lines are included.

(4) $U_2 - O_2 \geq U_1 - O_1$ or $U_1 - U_2 \leq O_1 - O_2$

combining (3) and (4) yields

(5) $U_1 - U_2 \leq O_1 - O_2 \leq U_1 - B_2$

or $25.0 \leq \Delta \leq 33.0$

TABLE 3-10

CIRRES Allocation for 2 O-D's

a) MONTREAL - HALIFAX
no of circuits required: 49

Circuit miles allocation		
Route	Cost of non-common links	
	miles	$
Mont		
Queb	165	4,899
692	28	1,718
689		
688		
Edmu		
798		
Fred		
788		
Sain		
786		
897		
895		
Ardo		
Hali		
Total	193	6,617

Average cost allocation		
Route	Cost of non-common links	
	miles	$
Mont		
696	28	1,292
Sher	66	1,430
693	77	1,337
692	56	599
689		
688		
Edmu		
798		
Fred		
788		
Sain		
786		
897		
895		
Ardo		
Hali		
Total	227	4,658

TABLE 3-10 (cont'd)

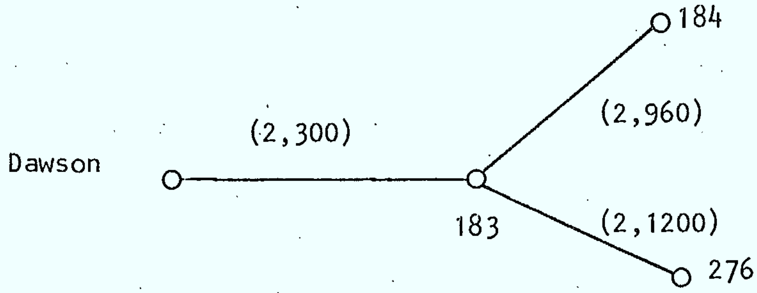
b) REGINA - VANCOUVER
no of circuits required: 120

Circuit miles allocation			Average cost allocation		
Route	Cost of non-common links		Route	Cost of non-common links	
	miles	$		miles	$
Regina			Regina		
389			389		
Swif			Swif		
395			395		
293			293		
294			294		
Mede	17	2,774	292	64	1,228
Leth	102	4,929	Leth	79	2,173
298			298		
299			299		
194			194		
195			195		
196			196		
Vanc			Vanc		
Total	119	7,703	Total	143	3,401

TABLE 3-11

Comparison between average cost and mileage for 2 links

a) Dawson - 183 - Cost Analysis
8 miles



(p,q) : p: nb of channels
q: operational circuits

		Transmission	Multiplexing
Nodes's costs:	Dawson T.R. 2ch	416,740	312,000
	183 J.R. 6ch	807,915	1,344,000

link's cost: 0 only 8 miles no repeaters

For CIRRES the average cost of link Dawson - 183 is made up of

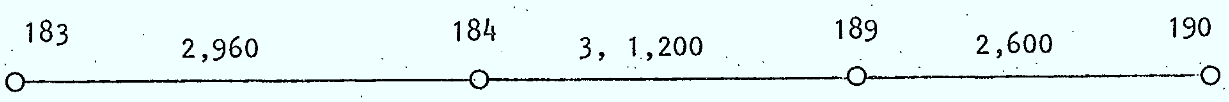
- Link cost		
- Dawson transmission	$\frac{416,740 \times 2}{2}$	416,740
- Dawson mutpx	$\frac{312,000 \times 300}{300}$	312,000
- 183 transmission	$\frac{807,915 \times 2}{(2+2+2)}$	269,305
- 183 mutpx	$\frac{1,344,000 \times 300}{(300 + 1,200 + 960)}$	163,900
Total		1,161,945

or $3,873 per circuit

TABLE 3-11 (cont'd)

b) <u>189 - 184</u>

193 miles



NØDES cost		TRSM	MTPX
189	1 R.R. 2 ch	497,560	0
184	1 R.R. 3 ch	552,725	0

LINK COST

189 - 184 : 193/35 miles	⟶	5 R.R. (3 ch)	2,763,625

FOR CIRRES

link 189 - 184 cost is made up of

- link cost		2,763,625
- node 189 cost	497,560 x 3/5	298,536
- node 184	552,725 x 3/5	331,635
TOTAL		3,393,796

(or $2,828/per circuit)

3.5 Sharing Block

The revenue sharing program was run for the "no private lines" scenario, and the results obtained under the three sharing schemes are presented in TABLE 3-12. The analysis of these results is presented in section 4.2 of this report.

Having proved the operational validity of the block, it was decided not to proceed to evaluate the "with private lines" case due to budget constraints and to the smallness of the marginal gain in information that would have been achieved.

3.6 Aging, Indexing and Depreciation

Aging I, a subprogram of the NPPS project dealing with computations of aging, indexing and depreciation had undergone a number of minor improvements and modifications during Phase III and its major testing within the Maritimes Experiment bears out its validity as well as its operational flexibility.

The analysis using Aging I, as shown below, is a purely theoretical exercise and the reader has to bear this fact in mind when he reads the results in Table 3-13 below.* The assumptions on the value of parameters are arbitrary:

- o life characteristics for switching and transmission equipment are assumed to follow the Iowa Survival Curve LO.0;
- o growth rates of these plants categories are 10% for 1971, 9.4% for 1970, 9.8% for 1969, 9.5% for 1968 and 8.5% for each of the earlier years;
- o average life for switching equipment is 20 YRS and maximum life 30 YRS;
- o average life for transmission equipment is 20 YRS and maximum life 30 YRS;
- o net salvage values are assumed zero;
- o reproduction indicies of 1.0 are assumed for both types of plant throughout the period.

---

* Computer output for Mass Properties is presented in Annex C.

Table 3-12

RESULTS OF COMMONWEALTH SHARING SCHEME
FOR PUBLIC MESSAGE SERVICE

NOTE: ALL DOLLAR FIGURES ARE IN THOUSANDS

RESULTS FOR ADJACENT PARTNERS:

	BCT	AGT	SASK	MANT	BCAN	NBT	MTT	TOT
INCURRED COSTS:	4298.	5126.	3575.	2532.	7338.	6654.	2755.	32276.
POST SET. REVENUE:	6127.	6901.	4371.	7877.	10338.	3756.	1353.	40722.
PRE SET. REVENUE:	4721.	8251.	4490.	8602.	10907.	3157.	593.	40722.
ASSIGNED PLANT INV.:	16292.	24583.	13454.	12779.	23033.	26390.	10893.	127422.
REV/ASSETS:	.38	.28	.32	.62	.45	.14	.12	.32
REV/COSTS:	1.43	1.35	1.22	3.11	1.41	.56	.49	1.26

RESULTS FOR NON-ADJACENT PARTNERS:

	BCT	AGT	SASK	MANT	BCAN	NBT	MTT	TOT
INCURRED COSTS:	4166.	4858.	6052.	3717.	11982.	1797.	5106.	37679.
POST SET. REVENUE:	8040.	10654.	4377.	5801.	18920.	1644.	4521.	53957.
PRE SET. REVENUE:	9907.	11459.	3175.	4228.	20502.	242.	4876.	54389.
ASSIGNED PLANT INV.:	15816.	23155.	22577.	18438.	37500.	7000.	20250.	144737.
REV/ASSETS:	.51	.46	.19	.31	.50	.23	.22	.37
REV/COSTS:	1.93	2.19	.72	1.56	1.58	.91	.89	1.43

THE DIFFERENCE OF 431.BETWEEN TOTAL PRE-AND POST-SETTLEMENT REVENUES IS PAID TO QUEBEC-TEL TO COVER THE COSTS IT INCURS AS INTERMEDIATE CARRIER

RESULTS FOR REGIONAL TRAFFIC:

	BCT	AGT	SASK	MANT	BCAN	NBT	MTT	TOT
INCURRED COSTS:	3052.	5889.	2348.	520.	38879.	4135.	5455.	60277.
ASSIGNED PLANT INV.:	11698.	28765.	8945.	2652.	123302.	16433.	21669.	213464.

SUBTOTAL FOR ADJ. AND NON-ADJ.

	BCT	AGT	SASK	MANT	BCAN	NBT	MTT	TOT
INCURRED COSTS:	8464.	9984.	9627.	6249.	19319.	8451.	7861.	69955.
POST SET. REVENUE:	14167.	17555.	8748.	13678.	29258.	5400.	5874.	94679.
PRE SET. REVENUE:	14627.	19710.	7665.	12831.	31409.	3399.	5469.	95110.
ASSIGNED PLANT INV.:	32108.	47738.	36031.	31217.	60533.	33390.	31143.	272159.
REV/ASSETS:	.44	.37	.24	.44	.48	.16	.19	.35
REV/COSTS:	1.67	1.76	.91	2.19	1.51	.64	.75	1.35

THE DIFFERENCE OF 431.BETWEEN TOTAL PRE-AND POST-SETTLEMENT REVENUES IS PAID TO QUEBEC-TEL TO COVER THE COSTS IT INCURS AS INTERMEDIATE CARRIER

	BCT	AGT	SASK	MANT	BCAN	NBT	MTT	TOT
TOTAL INST. ASSETS	58999.	94969.	56450.	41628.	242215.	65100.	69705.	629067.

% OF ASS. PLANT INV. BY SERVICE

	BCT	AGT	SASK	MANT	BCAN	NBT	MTT	TOT
ADJACENT:	27.6	25.9	23.8	30.7	9.5	40.5	15.6	20.3
US:	5.9	.7	4.5	1.7	7.5	4.0	.6	4.5
NON-ADJACENT:	26.8	24.4	40.0	44.3	15.5	10.8	29.1	23.0
REGIONAL:	19.8	30.3	15.8	6.4	50.9	25.2	31.1	33.9
MISCELLANEOUS:	3.5	3.9	.3	.4	5.1	5.8	16.2	5.3
TELEVISION:	9.4	5.6	4.6	5.3	5.5	1.0	3.6	5.1
UNASSIGNED:	6.9	9.2	11.0	11.3	6.0	12.7	3.8	7.8

Table 3-12 (cont'd)

RESULTS OF OLD COMMONWEALTH

RESULTS FOR ADJACENT & NON-ADJACENT PARTNERS

	BCT	AGT	SASK	MANT	BCAN	NBT	MTT	TOT
INCURRED COSTS:	8464.	9984.	9627.	6249.	19319.	8451.	7861.	69955.
POST SET. REVENUE:	11507.	13574.	13089.	8496.	26266.	11490.	10688.	95110.
PRE SET. REVENUE:	14627.	19710.	7665.	12831.	31409.	3399.	5469.	95110.
ASSIGNED PLANT INV.:	32108.	47738.	36031.	31217.	60533.	33390.	31143.	272159.
REV/ASSETS:	.36	.28	.36	.27	.43	.34	.34	.35
REV/COSTS	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36

WHICH SETTLEMENT SCHEME DO YOU WANT?
1.NEW COM. 2.OLD COM. 3.TCTS 4.STOP

RESULTS OF TCTS SCHEME

RESULTS FOR ADJACENT & NON-ADJACENT PARTNERS

	BCT	AGT	SASK	MANT	BCAN	NBT	MTT	TOT
INCURRED COSTS:	8464.	9984.	9627.	6249.	19319.	8451.	7861.	69955.
POST SET. REVENUE:	11431.	14396.	12958.	9134.	24914.	11537.	10740.	95110.
PRE SET. REVENUE:	14627.	19710.	7665.	12831.	31409.	3399.	5469.	95110.
ASSIGNED PLANT INV.:	32108.	47738.	36031.	31217.	60533.	33390.	31143.	272159.
REV/ASSETS:	.36	.30	.36	.29	.41	.35	.34	.35
REV/COSTS	1.35	1.44	1.35	1.46	1.29	1.37	1.37	1.36

TABLE 3-13

Summary of AGING I Results for Maritime Experiment
for the Totals of NPPS Network

Unit = $,000 , SRV = L0.0

	NPPS system totals before M.E.		NPPS system totals after M.E.	
	A S L	E L G	A S L	E L G
Switching Eqp.				
GTP Historical	196,200	196,200	211,600	211,600
GA Initial	2,063	2,063	2,225	2,225
GA Current	22,629	22,629	24,405	24.405
Accumulated Depn	54,849	68,034	59,154	73,374
Depn Reserve Ratio	28.0 %	34.7 %	28.0 %	34.7 %
Annual Depn	9,582	12,021	10,334	12,964
Depn Rate	5.0 %	6.5 %	5.0 %	6.5 %
Transmission Eqp.				
GTP Historical	385,927	385,927	386,083	386,083
GA Initial	4,058	4,058	4,059	4,059
GA Current	44,510	44,510	44,528	44,528
Acc. Depn	107,888	133,823	107,932	133,877
Depn Res. Ratio	28.0 %	34.7 %	28.0 %	28.0 %
Annual Depn	18,848	23,645	18,856	23,654
Depn Rate	5.0 %	6.5 %	5.0 %	6.5 %

The reader may notice that depreciation rates and reserve ratios for ASL method are lower than those for ELG method, correctly reflecting the different philosophies of these depreciation methods. One may also observe that depreciation rates and reserve ratios for switching and transmission equipment are identical, on account of identical assumptions being taken for various inputs for both plants types, as described above.

3.7 Accounting Block

For the sake of completeness of the Maritime experiment, two multi-period simulations were performed using the financial data of Maritimes Telephone for 1974. These simulations can also be seen as an application of the block "MULTIR" in the program "SIR". The results of these simulations appear in the Appendix "B".

We now describe these two simulations. In a first step, we have to generate the vector of NON-BEADS for the year 1974, and also the matrix coefficients, using the values of the BEADS for the same year. The result of this step is to generate the 52 variables used in the simulatenous equation system. In a second step we generate the financial statements (Balance Sheet, Funds Statement, Income Statement) for the beginning and the end of the year and some ratios are calculated. As in the simultaneous equations we put the predetermined variables at their historical values, the financial statements for the end of the year reflecting the values which appear in the BEADS and NON-BEADS vectors. In a third step we go to the multi-period simulation. The difference between the two simulations we performed is in the forecasted values for the BEADS. In the first simulation, the forecasted values are obtained from the beginning of the year (1974) of the corresponding variables, without using any information pertaining to the end of the year values for some variables. These forecasted values appear in the vectors "M74", and "S75". In the second simulation, we took the end of the year values for some variables (i.e. AD, EQ, GTP, L, PR, RE, UCCO) while the remaining BEADS variables took the same figures as in the first simulation. For the simultaneous equations the list of the predetermined variables, and consequently the list of the endogeneous variables, remain unchanged in the two simulations. Finally, the results of these simulations appear under the column "Variables Endogènes" in the printout appearing in the Appendix "B".

3.8 Assessment and Conclusions

In conducting this Maritimes Region Experiment, the NPPS simulation model has been successfully used on a meaningful problem of large size including all Level 4 switching nodes in a region. On a technical level, the conduct of the experiment has permitted the consolidation and implementation of programs and modules following the conversion to the CSC Computer System, a conversion necessitated by the need to treat problems of a meaningfully large scale. More specifically, the following have been achieved:

- An initial insight into the cost of Private Line Service
- The constituent modules and linkages are operational
- The operational use of several costing criteria (average and marginal costs) and hence the proof of ability to use almost any definition of costs
- Improvement of the logical and conceptual quality of the algorithms and programs, when tested on large problems
- Ability to achieve essentially optimal solutions at reasonable cost
- Very significant reductions in operating cost due to program conceptual developments and software improvements.

4. EVALUATION OF THE MODELS

4.1 Objectives achieved

The entire National Planning and Policy Simulation system has been designed to be operational, flexible, detailed, and improvable. It is operational because the relationships and variables in the model do not stay at the conceptual level but in fact measurements are obtained. It is flexible because many "blocks" can be used separately or in combination without using the entire system. The details are such that a professional in the field of telecommunications finds sufficient realism in the inputs, outputs and relationships of the model so that he can readily start a meaningful discussion. Finally, the system is certainly perfectible since it is modular.

From the point of view of the general problems to be solved, the NPPS system takes into account the following aspects:

o On the "demand" side:

  - several services are considered, thus it is a multicommodity problem;

  - although no reaction to tariffs is described, the time profiles of demand are useful inputs to study such reactions.

o On the "supply side:

  The facilities are used in common, therefore the circuit assignment (allocation) and the capital deployment (expansion or capacity constraints relaxation) form important problems. Costing procedures for embedded, current and prospective evaluations are available.

o On the "institutional" side:

  - interregional messages are processed by several carriers, therefore a revenue sharing problem must be solved;

  - this multicarrier feature also gives rise to the problem of evaluating various routing practices;

  - as a matter of fact the entire system has been designed to evaluate the possible advantages of some global planning.

The most important achievement in the NPPS Model is the simultaneous treatment of operational, costing, financial and economic variables and subsystems in an interactive coherent manner.

The main objective of the project has been to provide DOC with a tool which can be used to help the Department to evaluate policy options and to establish or monitor the implementation of telecommunications policy. In view of this objective the model has been formulated to be capable of analyzing different modes of operation of the Canadian inter-city telecommunications network and the financial implications of different scenarios for the participating carriers. The term "scenario" has been understood to represent a sufficiently broad meaning in order to satisfy the objectives. In specific terms, scenarios were to be "built" by altering any one or more of the following: data base, costing rules, accounting rules, institutional arrangements (e.g. revenue sharing), operational parameters (e.g. quality of service) and financial parameters (e.g. interest rate or debt/capital ratio).

A particular and main objective of the project was to provide a capability of deriving cost measures for the various services in the Canadian inter-city telecommunications network utilizing various costing concepts. In this regard two major considerations were kept in focus:

- o to provide suitable correspondence with the costing procedures emanating from the CTC Cost Inquiry, and

- o to design the costing algorithms in the context of the operation of the integrated network.

This second aspect has been of particular significance since the CTC Cost Inquiry terms of reference specifically excluded the consideration of services jointly provided with carriers outside of CTC's jurisdiction. Since the provision of services in the inter-city network is a multi-commodity problem - in an integrated network - the particular importance of this second aspect had to be recognized.

Bearing in mind the objectives, the methodology selected for the problem solution again incorporated two main considerations:

- o to assemble the blocks comprising the model from algorithms capable of accommodating and describing the relationship of data elements, constraints and parameters at a fine level of disaggregation, and

- o to treat the problems arising from the operation of the switching and transmission networks utilizing a "global" approach, as opposed to dealing with the sums of subsystems.

The implementation of the first consideration was essential in order to provide for sufficient flexibility and sensitivity in building the simulation scenarios. The importance of this aspect is obvious when the construction of simulation scenarios is envisaged as defining a simultaneous set of data elements, constraints and parameters.

The implementation of the second consideration was important in order to provide the capability of responding to questions posed in the context of an integrated network requiring techniques and criteria for global optimization. Apart from the usefulness of global optimization techniques for planning purposes their significance is particularly apparent when addressing service costing problems in a joint production environment, where the cost by service is defined as the increase in the aggregate costs of the total system as the result of adding the particular service. Quite obviously, the limits of additional costs imposed by adding a service (or increasing a service) are determined by some degree of rationality. In the extreme case, the maximum degree of rationality is that of satisfying the requirements of a global optimum: where the global optimum may be expressed in terms of objective functions of various definitions. It is recognized that in real life the achievement of a global optimum is not possible. Telecommunications systems evolved and evolve by responding to demand at various points on the time scale. Additions to the system are made in response to existing and anticipated demands using the best judgement at the time. Consequently, searching for the "true" additional cost caused by a service would require the re-creation of the "history" of the system. This would clearly be an impossible task. The global optimization technique is an effective, practicable approach for service costing based on causality.

The implementation of the foregoing two major considerations, the time level of disaggregation of data and the global optimization technique, imposed a considerable problem of size in the development of the computer software.

To support the attainment of the main objectives, it was essential to provide, within the model, extensive means of associating different operational modes and institutional arrangements (scenarios) with economic and financial categories and to express them in such terms. Accordingly, the creation of a complex interlocking structure of asset valuation, aging, indexing, financial and accounting algorithms was called for. In basic terms, the ultimate product obtained by these algorithms is the system of financial statements. These reflect the assets (primarily plant) vis-à-vis the sources, i.e. liabilities, resulting from the various financial sourcing strategies, and reflect the costs applicable to the revenues derived during a given period. The applicability of costs to revenues within the given period, i.e. the provision for the "matching principle", has been a major consideration in the development of the model. In addition to the requirement of producing financial statements as the indicators of the results of different scenarios, these algorithms were also necessary to provide both the means and the information required for the service costing procedures.

Particular emphasis was placed on the development of algorithms capable of dealing with the various methods of depreciation, treatment of deferred taxes and methods of capitalizing vs expensing. These issues also form an important part of the CTC Cost Inquiry. Having provided the computational capability within the framework of the model regarding these aspects, it became possible to study their implications in the overall context of the physical and financial operations, in addition to permitting the detailed analysis of the individual problem areas.

Finally, in order to express the financial results of the various scenarios, a powerful accounting block was designed and implemented utilizing algorithms which describe in detail the process employed in telecommunications utility accounting. The accounting algorithms were structured in such manner that they also permit a wide range of simulations in the domain of financial activites, the analysis of the consequences of various financial sourcing strategies, the determination of revenue requirements and/or the analysis of the consequences of different rate levels. It is interesting to note that the accounting block may be employed independently from the model as a whole and is generally applicable as a financial model regardless of the physical aspects of the corporate activities. In fact, the accounting block has already been extensively employed to analyze carriers' rate applications and the financial implications involved.

Evaluating the achievements in the terms of the objectives and major considerations described above, it may be concluded that the efforts of the project team have been successful. The detailed description of the accomplishments and the operation the NPPS model may be found elsewhere in this Report and in the previous project Reports, in the Users' Manual and in the computer program documentation comprising the voluminous output of this ambitious project.

In conclusion, it should be pointed out that apart from successfully responding to the intellectual challenge, the major accomplishment of the project in practical terms, has been the production of an operational model capable of dealing with complex problems of large size with sufficient realism to serve as an effective tool in the pursuit of Departmental objectives.

4.2 Comparative Analysis of the NPPS Estimates of Costs, Assets and Revenues.

The NPPS model has produced two sets of estimates of incurred costs, assets and revenues pertaining to the domain of intercarrier toll services. Both sets were established on the basis of very similar network configurations, the second experiment employing only a few more links and nodes in the Maritimes region. The first experiment however employed only 24 demand points, while the second, the Maritimes experiment, was considering 60. It should also be noted that in the first experiment, traffic was entirely estimated by a regression model, while observed traffic data between 17 cities was incorporated in the second. Comparison between estimated and observed traffic showed major differences (either positive or negative) in some instances.

In this section, we will compare costs and revenues of the TCTS companies for both experiments and try to relate these results to available TCTS benchmarks.

4.2.1 Cost Comparison

We will limit our cost comparison to plant investments since incurred costs represent a more or less constant ratio - 26% on the average - of assets. Main results concerning all TCTS companies appear in Table 4-1 (extracted from sample output shown in Table 3-12), and call for the following comments.

i) Total plant has increased by 3.1%, the main differences appearing for NBT and MTT where a few nodes and links have been added. Other differences result mainly from minor changes in the valuation functions between both experiments.

ii) Total assigned plant has increased for all carriers. The respective carrier's increase can be almost directly linked to the number of additional demand points considered in the second experiment. Overall assigned plant has increased by 37.7%, a logical consequence of the additional traffic.

iii) Plant assigned to regional traffic has increased in all instances except for BC Tel, which case will be analyzed later. Here again, the increase for each carrier can be related to the additional number of demand points introduced in its territory for the Maritimes experiment. Overall increase amounts to 37.7%. The decrease for BC Tel stems from the full allocation of costs used for revenue sharing . According to this principle, the full cost of a piece of equipment is allocated to the services which use it. Consequently, if one service takes more importance than another,

Table 4-1

Comparison of Plant Investments of NPPS and TCTS "DR" Plan

(1) = 24 Cities Experiment (2) = Maritimes Experiment

	Total Plant		Total Assigned Plant		Plant assigned to Regional Traffic		Plant assigned to Adjacent Traffic		Plant assigned to Interregional Traffic		Number of Demand Points		TCTS Benchmark
	1	2	1	2	1	2	1	2	1	2 (a)	1	2 (b)	(c)
BCT	59,094	58,999	42,429	54,928	15,608	11,698	10,216	16,292	16,605	26,938	4	5	100,470
AGT	92,736	94,969	51,005	86,232	15,753	28,765	14,957	24,583	20,295	32,884	2	6	90,910
SASK	56,602	56,450	34,357	50,240	4,523	8,945	9,478	13,454	20,356	27,841	2	5	60,790
MTS	40,900	41,628	26,176	36,924	0	2,652	11,212	12,779	14,964	21,493	1	2	63,770
BELL	243,517	242,215	216,000	227,682	115,443	123,302	21,507	23,033	79,049	81,347	9	11	324,840
NBT	60,029	65,100	27,913	56,832	3,669	16,433	10,253	26,390	18,991	14,009	2	9	33,000
MTT	57,362	69,705	23,232	67,056	0	21,669	2,711	10,893	20,521	34,494	1	10	33,820
TOTAL	610,239	629,067	421,112	579,894	154,997	213,464	80,354	127,424	185,781	239,006	21	48	707,600
Variation from (1) to (2)	+3.1%		+37.7%		+37.7%		+58.6%		+28.6%		+128%		

(a) Defined as: Total assigned - Regional - Adjacent

(b) Excluding U.S., CNCP, Quebec Tel, Newfoundland Tel

(c) Total FDR Assignment - Reference Year 1957 (e.g. interregional traffic increases more than regional traffic), its share of the total cost will be higher. Assume that the cost of an element is $1,000 and that 15% of its capacity is used for service A and 15% for service B in experiment 1. Full allocation of costs will consist in charging $500 to both A and B. Suppose that in experiment 2 respective usages are 20% and 60%. Cost allocation will then result in charging $250 and $750 to A and B respectively: Cost assigned to service A has dropped although general usage required by service A has increased.

iv) Total plant assigned to adjacent traffic has increased by 58.6%. Respective company increases can be related to the increase in the number of demand points for their adjacent partners.

v) Total plant assigned to interregional traffic has increased by 28.6%. The decrease observed for New Brunswick Telephone can be explained by the application of full cost allocation. In this instance, however, regional and adjacent traffic have increased more than interregional traffic.

vi) Values of plant assigned to interregional traffic estimated by the NPPS model are lower than the TCT S benchmarks figures, the main reasons for this being the use of a reduced network and also the fact that TCTS figures include local distribution plant not considered in NPPS.

It should also be noted that NPPS figures include plant assigned to traffic with Newfoundland, Quebec Telephone and Eastern Provincial Telephone. Total plant assigned to this type of traffic for all TCTS carriers in the network amounts to $33 million, out of which $11 million are for MTT. It is obvious that in this particular instance, a valid comparison with TCTS benchmarks whould exclude plant assigned to this traffic. The revised figure of $34M - $11M = $23 million compares more favorably to the benchmark of $34 million.

One can also notice that although total plant assigned to interregional traffic for the reduced network and in the Maritimes experiment amounts to only about 30% of the corresponding TCTS benchmark, the ratio improved to 56% for the Maritimes carriers, a logical consequence of improving network description in the considered region.

4.2.2 Revenues Comparison

Pre- and post-settlement revenues for the second experiment, as well as TCTS benchmarks for 1971 are presented in Table 4-2 (extracted from sample output shown in Table 3-12*).

No comparisons will be made between 1st and 2nd experiment results. Revenue calculations in the first experiment were based on peak hour traffic and hence yielded overestimated results.

The following observations can be made:

i) Total pre-and post-settlement revenues as calculated by NPPS represent approximately 57% of the corresponding TCTS benchmark. NPPS revenues and TCTS benchmark comparisons by carriers show that the ratio varies from a low 44% for Bell Canada to a high 74% for MTT. This is certainly valuable information with regards to the regional representativity of the network used in the experiment.

ii) The fact that NPPS, when compared to TCTS benchmarks, accounts for only one-third of the costs and almost two-thirds of the revenues is not necessarily contradictory; this difference can be explained by two factors: first, as mentioned earlier, NPPS does not account for local distribution plant; secondly, revenues are certainly not proportional to the size of the network considered. As a matter of fact, revenues depend mainly on the population represented by the network and if all major population centres are considered in the reduced network - this is certainly the case for the Maritime experiment - the model will capture a larger portion of real revenues than of real costs.

4.2.3 Conclusions

One should not attempt to draw direct conclusions from the figures presented previously as "real life" costs or revenues for carriers since traffic parameters were only estimations in most instances.

What is important, however, is that the NPPS model is now able to execute operationally a set of complex and highly interrelated calculations pertaining to carriers' costs and revenues, enabling us to assess the sensitivities and impacts of various scenarios.

---

* Post-settlement revenues discussed here are those obtained using the new Commonwealth Sharing Scheme. Results of other distribution schemes can be seen in the sample output shown in Table 3-12.

TABLE 4-2

Comparison of Revenues estimated by NPPS and TCTS Benchmarks

	Nonadjacent Partners		Adjacent Partners		Adjacent and Nonadjacent		TCTS Benchmarks (b
	Pre-settlement	Post-settlement	Pre-settlement	Post-settlement	Pre-settlement	Post-settlement	
BCT	9,907	8,040	4,721	6,127	14,627	14,167	26,868
AGT	11,459	10,654	8,251	6,901	19,710	17,555	24,344
SASK	3,175	4,377	4,490	4,371	7,665	8,748	12,518
MTS	4,228	5,801	8,602	7,877	12,831	13,678	17,222
BELL	20,502	18,920	10,907	10,338	37,409	29,258	66,207
NBT	242	1,644	3,157	3,756	3,399	5,400	11,974
MTT	4,876	4,521	593	1,353	5,469	5,874	7,851
TOTAL	54,389 [a]	53,957 [a]	40,722	40,722	95,110 [a]	94,679 [a]	166.984

(a) Difference in pre-and post-settlement revenues represents costs incurred by Quebec Telephone as intermediate carrier.

(b) Reference Year: 1971.

5. FURTHER DEVELOPMENTS

5.1 Issues to be Addressed

The analytical and simulation capabilities of the models as they presently exist, are discussed in the preceeding chapter. Further developments should be aimed at widening these capabilities within the overall framework of studying in an integrated fashion the costs of all Canadian inter-urban telecommunications services.

In parallel with further development, it is essential to explore to the utmost the potential for extracting useful information from existing modules. This in its turn may well lead to minor but significant programming re-orientations or improvements.

The possible developments are presented in the following paragraphs in accordance with the apparent level of effort required for their implementation.

5.2 Minor or Short Term Developments

At an early date, the following minor modifications could be introduced:

- Develop programs to carry out consistency checks on the data base;
- Incorporate advanced start procedures into the Circuit allocation program (CIRRES) and establish computer cost benchmarks for obtaining optimal allocations using CIRRES;
- Up-grade the efficiency of all programs in order to make maximum use of available cost saving procedures. Particular attention should be devoted to:
  - the calculation of usage of facilities
  - the revenue sharing block

  These being the most expensive programs to run.
- Evaluate further the concept and use of "economic-CCS" for dimensioning the switching network for purposes of incremental costing and add refinements where practicable;
- Automate the capability to examine the impacts of evolving demand requirements;
- Operationally tie-in the aging, indexing and depreciation algorithms to the costing block, so as to permit simulations on the basis of other than "current","replacement" costs. This will additionally provide the capability to produce financial reports based on indexed value of assets as well as upon book value of assets, as is currently done.

- Development of routines to isolate the dual variable values in the circuit allocation program so as to furnish the marginal costs for an additional circuit on any link, as a function of a given demand requirement and network configuration;

- Additional costing concepts such as average and marginal cost based on ultimate (long-run) capacity.

5.3 Major or longer-term developments

The first priority in major or longer-term developments should be in implementing the following:

- The introduction of upper-bound and genralized upper-bound techniques in the circuit allocation program (CIRRES) in order to provide increased flexibility and efficiency through reduction in the size of the required matrix, and hence to permit consideration of such additional factors as survivability and bounding on network expansion;

- Operationally find ways to consider all Level 4 facilities either through problem segmentation (a regional bulge) or through expansion of problem size limitations;

- Introduce other services such as TWX and WATS as well as the capability to consider transmission via satellite linkages. This is primarily a data problem, but one of significant proportions. Cost definition problems are also associated with the satellite.

- Continued use and extension of the goal programming approach in the Accounting Block, especially in a multi-period context.

Amongst activities of less pressing need, but nonetheless useful, the following could be included:

- Linking tariffs and demand, through use of price-elasticity estimators;

- Extending the circuit allocation program (CIRRES) so as to examine:

    - computation of the critical time prior to expansion of the transmission network (see Interim Report Phase II);

    - expansion over time to identify benefits from economies of scale with finite horizons;

    - introduction of a mixed-integer algorithm to account for major cost function jumps or for the introduction of new technology;

    - develop a measure of quality of service as a function of allocation on the transmission network.

APPENDIX A

ACCOUNTING

BLOCK

FLOW CHARTS

ORGANIGRAM OF SIR

(When the names of the subprograms are written without details, this means that the steps are given in another organigram).

START

DATAGES

Printout of the vector x

Number of the x components which the user wants to change for this simulation.

If none is to be changed go to

If some are to be changed, give their value.

Give the numbers of exogenous and endogenous variables

CONTRA

Calculation of $x_2 = - A_2^{-1} A_1 x_1$

Calculation of the ratios

Printout of x_2 and the ratios

Do you want a printout of the balance sheet and funds statement? If no go to

If yes, there is an updating of variables and then a printout.

Do you want a next period simulation?

yes / no

Respecification of the numbers of variables which are to be endogenous (they can be the same numbers as before)

MULTIR

Do you want another simulation?

yes / no

END

ORGANIGRAM OF DATAGES

START

↓

Give the values of 74 beads

↓

Calculation of non-beads (43)

↓

Construction of x with the help of beads and non-beads

↓

If wanted, printout the beads and the non-beads

↓

Construction of a vector PA containing coefficients that will be used in the subprogram CONTRA

↓

Construction of a vector IP containing data necessary for the calculation of ratios in SIR

↓

Construction of a vector CCE containing data necessary for the output of the balance sheet (by the subprogram BILAN)

↓

Construction of a vector FS containing data necessary for the output of the funds statement (by the subprogram FUNDS)

ORGANIGRAM OF CONTRA

START

↓

Give the number of predetermined ratios

If none, then go to →

If some, then for each give the values of coefficients corresponding to x

↓

Construction of A

↓

END

ORGANIGRAM OF MULTIR

START

↓

Give the values of the 40 beads, 17 optional beads, and 30 regression beads

↓

Give the number of the option

↓

Construction of x by a system of appropriate equations (depending on the number of the option)

↓

Construction of PA, IP, CCE (the step is analogous to the one in DATAGES).*

↓

Printout of x

↓

END

(The organigrams of BILAN and FUNDS are not given since these subprograms merely state how to arrange the printout for correct presentation).

---

* Note that in the actual state of the programs, there is a lack of data to permit a consistent output of the balance sheet, so that after a simulation for the next period, answer no when the program asks for an optional output of the balance sheet.

APPENDIX B

MARITIMES EXPERIMENT

RESULTS OF

ACCOUNTING BLOCK

SIMULATIONS

SIR

DONNER LA VALEUR (EN VECTEUR) DES 74 VARIABLES BEAD (DANS L'ORDRE DU TEXTE).SI VOUS MANQUEZ D'ESPACE SUR UNE LIGNE ,CONTINUER SUR LA SUIVANTE.

⎕:

M74

DESIREZ-VOUS L'IMPRESSION DES RESULTATS : BEAD ET NON-BEAD .(REPONDRE OUI OU NON)

OUI

	BEAD		NON-BEAD
1	33538.00000	1	73358.00000
2	37854.00000	2	36360.00000
3	2405.00000	3	214.00000
4	439.00000	4	0.26941
5	1381.00000	5	0.07560
6	7275.00000	6	125000.00000
7	8473.00000	7	30500.00000
8	12154.00000	8	0.07186
9	14446.00000	9	0.51594
10	6801.00000	10	8185.00000
11	4480.00000	11	8648.00000
12	10805.00000	12	243473.00000
13	2120.00000	13	21495.00000
14	1167.00000	14	24310.00000
15	0.10750	15	100892.00000
16	0.08600	16	225892.00000
17	0.00000	17	9681.00000
18	0.10000	18	1084.00000
19	317179.00000	19	0.02898
20	73706.00000	20	0.02898
21	4083.00000	21	5896.00000
22	877.00000	22	6655.00000
23	12261.00000	23	¯2293.00000
24	9234.00000	24	136.00000
25	2249.00000	25	2927.00000
26	16990.00000	26	5815.00000
27	0.00000	27	614.00000
28	0.00000	28	13.00000
29	20106.00000	29	0.05403
30	56476.00000	30	0.08228
31	0.00000	31	327.00000
32	114500.00000	32	257.00000
33	10500.00000	33	¯231.00000
34	12860.00000	34	595.00000
35	33269.00000	35	23343.71736
36	759.00000	36	230100.71327
37	1274.00000	37	1432.3 0579
38	5231.00000	38	169894.61905
39	0.00000	39	272177.00000
40	312.00000	40	272177.00000

41	159.00000	41	62016.00000
[redacted]			
43	156.00000	43	6911.00000
44	13606.00000		
45	1190.00000		
46	63063.00000		
47	2286.00000		
48	0.10145		
49	0.25000		
50	0.00000		
51	0.00000		
52	0.28000		
53	862.00000		
54	2524.00000		
55	5157.00000		
56	0.00000		
57	0.12500		
58	0.00000		
59	95690.00000		
60	262764.00000		
61	10425.00000		
62	55392.00000		
63	26614.00000		
64	22783.00000		
65	4070.00000		
66	66462.00000		
67	1635.00000		
68	20.00000		
69	15680.00000		
70	9933.00000		
71	3170.00000		
72	2431.00000		
73	4176.00000		
74	13883.00000		

VOICI LA LISTE DES VARIABLES DU SYSTEME D'EQUATIONS SIMULTANEES ET LEUR VALEUR POUR CETTE SIMULATION.

1	*AD*	73706.00000
2	*ADO*	66462.00000
3	*CURDTX*	5896.00000
4	*DIVI*	5231.00000
5	*DEPN*	14446.00000
6	*EQ*	56476.00000
7	*EQO*	55392.00000
8	*GCE*	63063.00000
9	*GTP*	317179.00000
10	*GTPO*	262764.00000
11	*IDC*	1167.00000
12	*LO*	95690.00000
13	*L*	125000.00000
14	*NETINC*	8185.00000

15	NEWDEBT	30500.00000
16	NIA	6911.00000
17	OPRV	73358.00000
18	OPXP	36360.00000
19	OTHINC	214.00000
20	PR	20106.00000
21	PRDTX	759.00000
22	PRO	10425.00000
23	PUCO	13883.00000
24	RE	24310.00000
25	REPL	1190.00000
26	REO	22783.00000
27	ADJD	0.00000
28	ADJP	0.00000
29	ADJR	0.00000
30	ADJU	0.00000
31	CCA	23343.71736
32	DELDCH	614.00000
33	DELDCR	136.00000
34	DELCTI	¯2293.00000
35	DELCL	2927.00000
36	DELINV	13.00000
37	DELEQ	1084.00000
38	DELOCA	5815.00000
39	DELPR	9681.00000
40	DEPDIF	0.00000
41	DPRTVE	327.00000
42	DPRTVC	257.00000
43	GETV	5157.00000
44	GETVO	4176.00000
45	LAND	2524.00000
46	LANDO	2431.00000
47	NSV	862.00000
48	OTHADJ	159.00000
49	OTHEXP	1432.) 0579
50	RET	8648.00000
51	UCC	230100.71327
52	UCCO	169894.61905

DONNER LE NUMERO DES VARIABLES DONT VOUS DESIREZ CHANGER LA VALEUR POUR CETTE SIMULATION (TAPER 0 SI AUCUN
⎕:
0
PARMI LA LISTE PRECEDENTE ,DONNER (EN VECTEUR) LE NUMERO DES VARIABLES PREDETERMINEES
⎕:

```
      PRD
PARMI CETTE MEME LISTE DONNER LE NUMERO DES VARIABLES ENDOGENES
⎕:
      END
LE SOUS-PROGRAMME CONTRA SERT A CALCULER AUTOMATIQUEMENT LA MATRICE DES COEFFICIENTS:A
DONNER LE NOMBRE DE RAPPORTS PREDETERMINES (TAPER 0 SI AUCUN).
⎕:
      0
NOUS ALLONS MAINTENANT CALCULER LES RATIOS
CHANGER DE PAGE ET TAPER SUR 'RETURN
```

LA SOLUTION DU SYSTEME D'EQUATIONS EST LA SUIVANTE

VARIABLES PREDETERMINEES

2	ADO	66462.00
4	DIVI	5231.00
7	EQO	55392.00
10	GTPO	262764.00
12	LO	95690.00
15	NEWDEBT	30500.00
17	OPRV	73358.00
18	OPXP	36360.00
19	OTHINC	214.00
21	PRDTX	759.00
22	PRO	10425.00
23	PUCO	13883.00
25	REPL	1190.00
26	REO	22783.00
27	ADJD	0.00
28	ADJP	0.00
29	ADJR	0.00
30	ADJU	0.00
32	DELDCH	614.00
33	DELDCR	136.00
34	DELCTI	-2293.00
35	DELCL	2927.00
36	DELINV	13.00
37	DELEQ	1084.00
38	DELOCA	5815.00
39	DELPR	9681.00
40	DEPDIF	0.00
41	DPRTVE	327.00
42	DPRTVC	257.00
43	GETV	5157.00
44	GETVO	4176.00
45	LAND	2524.00
46	LANDO	2431.00
47	NSV	862.00
48	OTHADJ	159.00
49	OTHEXP	1432.91
50	RET	8648.00
52	UCCO	169894.62

VARIABLES ENDOGENES

1	AD	73706.00
3	CURDTX	5896.00
5	DEPN	14446.00
6	EQ	56476.00
8	GCF	63063.00
9	GTP	317179.00
11	IDC	1167.00
13	L	125000.00
14	NETINC	8185.00
16	NIA	6911.00
20	PR	20106.00
24	RE	24310.00
31	CCA	23343.72
51	UCC	230100.71

RATIOS

DCR	0.53803
PCR	0.07443
DPR	0.75691
ROREC	0.08695
RORC	0.08122
ITCI	1.96601
ITCE	2.82462
RORBI	0.08455
RORBE	0.08532

DESIREZ-VOUS L'IMPRESSION DE: BALANCE SHEET,FUNDS STATEMENT,INCOME STATEMENT?(REPONDRE OUI OU NON)
OUI
CHANGER DE PAGE ET TAPER SUR 'RETURN

BALANCE SHEET

ASSETS

	BEGINN.OF YEAR	END OF YEAR
TEL.PL.+COST	262764.0	317179.0
ACC.DEP'N	66462.0	73706.0
TEL. PLANT	196302.0	243473.0
INVESTMENTS	4070.0	4083.0
CASH+TEMP.INV.	3170.0	877.0
OTH.CUR.ASSETS	15680.0	21495.0
CURRENT ASSETS	18850.0	22372.0
DEF.CH.DEBT.	0.0	0.0
DEF. CH. OTHER	0.0	0.0
DEF. CHARGES	1635.0	2249.0
TOTAL ASSETS	220857.0	272177.0

LIABILITIES

	BEGINN.OF YEAR	END OF YEAR
PREF. SHARES	10425.0	20106.0
COMMON SHARES	55392.0	56476.0
RETAINED EARNING	22783.0	24310.0
SHAREHOLD.CAP.	88600.0	100892.0
DEBT	95690.0	125000.0
TOTAL CAP'N TCO	184290.0	225892.0
CURRENT LIA.	9933.0	12860.0
DEFERRED TAXES	26614.0	33269.0
DEF.CREDITS OTH.	20.0	156.0
DEF.CREDITS	26634.0	33425.0
TOTAL LIA.	220857.0	272177.0

FUNDS STATEMENT

SOURCES :

NET INCOME	8185.0
PREFERRED DIVIDENDS	1274.0
COMMON DIVIDENDS	5231.0
INCOME RETAINED	1680.0
DEFERRED TAXES CURRENT	5896.0
DEFERRED TAXES PRIOR	759.0
DEFERRED TAXES	6655.0
DEPRECIATION	14446.0
DEPRECIATION (TOOLS)EXP'D	327.0
INTEREST DURING CONSTRUCTION	1167.0
OTHER NON-CASH CHARGES	13606.0
NON-CASH CHARGES	0.0
ADDITIONS TO L.T.D.	30500.0
LESS REPAYMENTS	1190.0
NET CHANGE IN DEBT	29310.0
PREFERRED ISSUED	9681.0
COMMON ISSUED	1084.0
TOTAL SOURCES	62016.0

USES:

GROSS CONSTRUCTION	63063.0
INTEREST DURING CONSTRUCTION	1167.0
DEPRECIATION (TOOLS) CAP'D	257.0
CHARGES NOT REQUIRING FUNDS	1424.0
NET CONSTRUCTION EXPENDITURES	61639.0
INVESTMENTS	13.0
MISCELLANEOUS	-231.0
CHANGE IN WORKING CAPITAL	595.0
TOTAL USES	62016.0

INCOME STATEMENT

OPERATING REVENUE	73358.0
OPERATING EXPENSES	36360.0
DEPRECIATION	14446.0
TAXABLE OTHER INCOME	214.0
	22766.0
NON-TAXABLE OTHER INCOME	0.0
INTEREST DURING CONSTRUCTION	1167.0
	23933.0
INCOME TAXES	7275.0
	16658.0
DEBT SERVICE CHARGES	8473.0
NET INCOME	8185.0


```
DESIREZ-VOUS EFFECTUER UNE SIMULATION POUR LA PERIODE T+1 ?(REPONDRE OUI OU NON)
OUI
LES VARIABLES PREDETERMINEES ET ENDOGENES SONT-ELLES LES MEMES? (REPONDRE OUI OU NON.)
OUI
LE SOUS-PROGRAMME MULTIR SERT A GENERER LES DONNEES POUR LA PERIODE T+1
DONNER LA VALEUR DES 40 VAR. BEADS
⎕:
      S75[⍳40]
DONNER LA VALEUR DES 17 VAR. OPTIONAL BEADS (TAPER 0 POUR LES NON PERTINENTES
⎕:
      S75[40+⍳17]
DONNER LA VALEUR DES 30 VAR. REGRESSION BEADS
⎕:
      S75[57+⍳30]
DONNER LE NUMERO DE L'OPTION NON-BEADS
⎕:
      1
```

Les vecteurs suivants: END, M74, PRD, S75, Z72 sont gardés en mémoire afin de ne pas avoir à réécrire chaque fois toutes les données pertinentes. Voici leurs composantes telles que données comme input aux calculs subséquents. Ces vecteurs contiennent les valeurs des variables BEADS pour la simulation de la période t+1.

M74

33538 37854 2405 439 1381 7275 8473 12154 14446 6801 4480 10805 2120 1167 0.1075 0.086 0 0.1 317179 73706 4083 877
12261 9234 2249 16990 0 0 20106 56476 0 114500 10500 12860 33269 759 1274 5231 0 312 159 0 156 13606 1190 63063
2286 0.10145 0.25 0 0 0.28 862 2524 5157 0 0.125 0 95690 262764 10425 55392 26614 22783 4070 66462 1635 20 15680
9933 3170 2431 4176 13883

PRD

2 4 7 10 12 15 17 18 19 21 22 23 25 26 27 28 29 30 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 52

END

1 3 5 6 8 9 11 13 14 16 20 24 31 51

S75

55392 22783 10425 95690 13883 2431 4176 262764 66462 26614 15680 9933 4070 0.082275 0.07 169756 0.02898 0.02898 0.03
0 0.1 0.125 0.09 0.055 0.09 0.5159428 0.0525 1190 0 136 614 759 159 0 0 0 0 0 0.56 0.2694 0.207087 63063 73368
0 0 0 0 9681 0 30500 0 0 0 1084 ¯2293 5231 0 0 0.032912 0 0.0498189 0 0.099676 0 0.007958 0 0.016259 0 0.26941
0 0.12048 0 0.1 0 0.09906 0 0.44768 0 0.292975 0 0.074128 0 0.252983 0 0.012873 0 0.0335096

VOICI LA VALEUR DES 52 VARIABLES

1AD	0.00
2ADO	66462.00
3CURDTX	0.00
4DIVI	5231.00
5DEPN	14446.06
6EQ	0.00
7EQO	55392.00
8GCE	63063.10
9GTP	317179.01
10GTPO	262764.00
11IDC	849.00
12LO	95690.00
13L	0.00
14NETINC	0.00
15NEWDEBT	30500.00
16NIA	0.00
17OPRV	73368.00
18OPXP	28724.58
19OTHINC	214.02
20PR	0.00
21PRDTX	759.00
22PRO	10425.00
23PUCO	13883.00
24RE	0.00
25REPL	1190.00
26REO	22783.00
27ADJD	0.00
28ADJP	0.00
29ADJR	0.00
30ADJU	0.00
31CCA	22960.95
32DELDCH	614.00
33DELDCR	136.00
34DELCTI	-2293.00
35DELCL	2926.42
36DELINV	13.05
37DELEQ	1084.00
38DELOCA	5814.99
39DELPR	9681.00
40DEPDIF	0.00
41DPRTVE	314.84
42DPRTVC	247.38
43GETV	5157.01
44GETVO	4176.00
45LAND	2524.11
46LANDO	2431.00
47NSV	862.01
48OTHADJ	159.00

```
 49OTHEXP                 2113.22
 50RET                    8648.09
 51UCC                  229609.50
 52UCCO                 169756.00
LE SOUS-PROGRAMME CONTRA SERT A CALCULER AUTOMATIQUEMENT LA MATRICE DES COEFFICIENTS:A
DONNER LE NOMBRE DE RAPPORTS PREDETERMINES (TAPER 0 SI AUCUN).
⎕:
      0
NOUS ALLONS MAINTENANT CALCULER LES RATIOS
CHANGER DE PAGE ET TAPER SUR 'RETURN
```

LA SOLUTION DU SYSTEME D'EQUATIONS EST LA SUIVANTE

VARIABLES PREDETERMINEES

2	ADO	66462.00
4	DIVI	5231.00
7	EQO	55392.00
10	GTPO	262764.00
12	LO	95690.00
15	NEWDEBT	30500.00
17	OPRV	73368.00
18	OPXP	28724.58
19	OTHINC	214.02
21	PRDTX	759.00
22	PRO	10425.00
23	PUCO	13883.00
25	REPL	1190.00
26	REO	22783.00
27	ADJD	0.00
28	ADJP	0.00
29	ADJR	0.00
30	ADJU	0.00
32	DELDCH	614.00
33	DELDCR	136.00
34	DELCTI	-2293.00
35	DELCL	2926.42
36	DELINV	13.05
37	DELEQ	1084.00
38	DELOCA	5814.09
39	DELPR	9681.00
40	DEPDIF	0.00
41	DPRTVE	314.84
42	DPRTVC	247.38
43	GETV	5157.01
44	GETVO	4176.00
45	LAND	2524.11
46	LANDO	2431.00
47	NSV	862.01
48	OTHADJ	159.00
49	OTHEXP	2113.22
50	RET	8648.09
52	UCCO	169756.00

VARIABLES ENDOGENES

1	AD	73758.86
3	CURDTX	6056.38
5	DEPN	14520.72
6	EQ	56476.00
8	GCE	66845.91
9	GTP	320961.82
11	IDC	877.01
13	L	125000.00
14	NETINC	11774.53
16	NIA	10481.17
20	PR	20106.00
24	RE	27880.20
31	CCA	23336.43
51	UCC	233364.30

RATIOS

DCR	0.53339
PCR	0.07379
DPR	0.49909
RORFC	0.12897
RORC	0.09573
ITCI	2.46647
ITCE	3.88755
RORBI	0.10029
RORBE	0.10432

DESIREZ-VOUS L'IMPRESSION DE: BALANCE SHEET,FUNDS STATEMENT,INCOME STATEMENT?(REPONDRE OUI OU NON)
OUI
CHANGER DE PAGE ET TAPER SUR 'RETURN

[redacted] M[redacted]ime[redacted]per[redacted]t: [redacted]ula[redacted] po[redacted]la p[redacted]ode[redacted] ut[redacted]ant[redacted]mme[redacted]eur[redacted] dé[redacted] de [redacted]iode [redacted]
en t+1 les valeurs de fin de période en t.

LA SOLUTION DU SYSTEME D'EQUATIONS EST LA SUIVANTE

VARIABLES PREDETERMINEES			VARIABLES ENDOGENES		
2	ADO	73706.00	1	AD	82262.30
4	DIVI	5231.00	3	CURDTX	4911.34
7	EQO	56476.00	5	DEPN	17269.12
10	GTPO	317179.00	6	EQ	57560.00
12	LO	125000.00	8	GCE	67582.52
15	NEWDEBT	30500.00	9	GTP	374322.53
17	OPRV	73368.00	11	IDC	967.91
18	OPXP	34673.06	13	L	154310.00
19	OTHINC	236.55	14	NETINC	6683.87
21	PRDTX	759.00	16	NIA	4594.00
22	PRO	20106.00	20	PR	29787.00
23	PUCO	16990.00	24	RE	23520.03
25	REPL	1190.00	31	CCA	23351.81
26	REO	24310.00	51	UCC	233518.09
27	ADJD	0.00			
28	ADJP	0.00			
29	ADJR	0.00			
30	ADJU	0.00			
32	DELDCH	614.00			
33	DELDCR	136.00			
34	DELCTI	-2293.00			
35	DELCL	2662.44			
36	DELINV	845.59			
37	DELEQ	1084.00			
38	DELOCA	-0.01			
39	DELPR	9681.00			
40	DEPDIF	0.00			
41	DPRTVE	383.96			
42	DPRTVC	301.69			
43	GETV	6224.96			
44	GETVO	5157.00			
45	LAND	3046.82			
46	LANDO	2524.00			
47	NSV	1040.52			
48	OTHADJ	159.00			
49	OTHEXP	2550.84			
50	RET	10439.00			
52	UCCO	169756.00			

RATIOS

DCR	0.56878
PCR	0.10160
DPR	1.13866
ROREC	0.05676
RORC	0.06828
ITCI	1.66303
ITCE	2.24488
RORBI	0.07004
RORBE	0.07125

DESIREZ-VOUS L'IMPRESSION DE: BALANCE SHEET,FUNDS STATEMENT,INCOME STATEMENT?(REPONDRE OUI OU NON)
OUI

CHANGER DE PAGE ET TAPER SUR 'RETURN

APPENDIX C

MARITIMES EXPERIMENT

COMPUTER OUTPUT

FOR

AGING, INDEXING AND DEPRECIATION

FOR

MASS PROPERTIES

```
****************
*  ASL METHOD  *
****************
SRV CURVE= LO.O
AVG LIFE=20.000
MAX LIFE= 30
SALV RATE= O.
GTP-PRIME=    196200.0
INFL. INDEX= 1.0000  FOR PERIOD   1 TO 30
GROWTH RATE= 1.1000  FOR PERIOD   1 TO  1
             1.0940  FOR PERIOD   2 TO  2
             1.0980  FOR PERIOD   3 TO  3
             1.0950  FOR PERIOD   4 TO  4
             1.0850  FOR PERIOD   5 TO 30
DO YOU WISH TO CONTINUE: YES OR NO


GA INITIAL =      2062.8
GA CURRENT =     22628.5
GTP HISTORICAL =   196200.0
DEPRECIATION RESERVE =    54848.8 ( 27.96%)
ANNUAL DEPRECIATION =     9582.2 (  5.00%)
DO YOU WISH TO HAVE THE VINTAGES PRINTED
DO YOU WANT TO DO ANOTHER SIMULATION:YES OR NO




****************
*  ELG METHOD  *
****************
SRV CURVE= LO.O
AVG LIFE=20.000
MAX LIFE= 30
SALV RATE= O.
GTP-PRIME=    196200.0
INFL. INDEX= 1.0000  FOR PERIOD   1 TO 30
GROWTH RATE= 1.1000  FOR PERIOD   1 TO  1
             1.0940  FOR PERIOD   2 TO  2
             1.0980  FOR PERIOD   3 TO  3
             1.0950  FOR PERIOD   4 TO  4
             1.0850  FOR PERIOD   5 TO 30
DO YOU WISH TO CONTINUE: YES OR NO


GA INITIAL =      2062.8
GA CURRENT =     22628.5
GTP HISTORICAL =   196200.0
DEPRECIATION RESERVE =    68033.7 ( 34.68%)
ANNUAL DEPRECIATION =    12020.6 (  6.50%)
DO YOU WISH TO HAVE THE VINTAGES PRINTED
DO YOU WANT TO DO ANOTHER SIMULATION:YES OR NO
```

```
****************
*  ASL METHOD  *
****************
SRV CURVE= LO.O
AVG LIFE=20.000
MAX LIFE= 30
SALV RATE= O.
GTP-PRIME=    211600.0
INFL. INDEX= 1.0000  FOR PERIOD   1 TO 30
GROWTH RATE= 1.1000  FOR PERIOD   1 TO  1
             1.0940  FOR PERIOD   2 TO  2
             1.0980  FOR PERIOD   3 TO  3
             1.0950  FOR PERIOD   4 TO  4
             1.0850  FOR PERIOD   5 TO 30
DO YOU WISH TO CONTINUE: YES OR NO


GA INITIAL =       2224.7
GA CURRENT =      24404.6
GTP HISTORICAL =    211600.0
DEPRECIATION RESERVE =      59153.9 ( 27.96%)
ANNUAL DEPRECIATION =      10334.3 (  5.00%)
DO YOU WISH TO HAVE THE VINTAGES PRINTED


****************
*  ELG METHOD  *
****************
SRV CURVE= LO.O
AVG LIFE=20.000
MAX LIFE= 30
SALV RATE= O.
GTP-PRIME=    211600.0
INFL. INDEX= 1.0000  FOR PERIOD   1 TO 30
GROWTH RATE= 1.1000  FOR PERIOD   1 TO  1
             1.0940  FOR PERIOD   2 TO  2
             1.0980  FOR PERIOD   3 TO  3
             1.0950  FOR PERIOD   4 TO  4
             1.0850  FOR PERIOD   5 TO 30
DO YOU WISH TO CONTINUE: YES OR NO


GA INITIAL =       2224.7
GA CURRENT =      24404.6
GTP HISTORICAL =    211600.0
DEPRECIATION RESERVE =      73373.8 ( 34.68%)
ANNUAL DEPRECIATION =      12964.1 (  6.50%)
DO YOU WISH TO HAVE THE VINTAGES PRINTED
DO YOU WANT TO DO ANOTHER SIMULATION:YES OR NO
```

```
****************
*  ASL METHOD  *
****************
SRV CURVE= LO.0
AVG LIFE=20.000
MAX LIFE= 30
SALV RATE= 0.
GTP-PRIME=   385927.0
INFL. INDEX= 1.0000  FOR PERIOD   1 TO 30
GROWTH RATE= 1.1000  FOR PERIOD   1 TO  1
             1.0940  FOR PERIOD   2 TO  2
             1.0980  FOR PERIOD   3 TO  3
             1.0950  FOR PERIOD   4 TO  4
             1.0850  FOR PERIOD   5 TO 30
DO YOU WISH TO CONTINUE: YES OR NO


GA INITIAL =      4057.5
GA CURRENT =     44510.4
GTP HISTORICAL =   385927.0
DEPRECIATION RESERVE =    107888.0 ( 27.96%)
ANNUAL DEPRECIATION =     18848.2 (  5.00%)
DO YOU WISH TO HAVE THE VINTAGES PRINTED
DO YOU WANT TO DO ANOTHER SIMULATION:YES OR NO
```

```
****************
*  ELG METHOD  *
****************
SRV CURVE= LO.0
AVG LIFE=20.000
MAX LIFE= 30
SALV RATE= 0.
GTP-PRIME=   385927.0
INFL. INDEX= 1.0000  FOR PERIOD   1 TO 30
GROWTH RATE= 1.1000  FOR PERIOD   1 TO  1
             1.0940  FOR PERIOD   2 TO  2
             1.0980  FOR PERIOD   3 TO  3
             1.0950  FOR PERIOD   4 TO  4
             1.0850  FOR PERIOD   5 TO 30
DO YOU WISH TO CONTINUE: YES OR NO


GA INITIAL =      4057.5
GA CURRENT =     44510.4
GTP HISTORICAL =   385927.0
DEPRECIATION RESERVE =    133822.8 ( 34.68%)
ANNUAL DEPRECIATION =     23644.5 (  6.50%)
DO YOU WISH TO HAVE THE VINTAGES PRINTED
DO YOU WANT TO DO ANOTHER SIMULATION:YES OR NO
```

```
****************
*  ASL METHOD  *
****************
SRV CURVE= LO.0
AVG LIFE=20.000
MAX LIFE= 30
SALV RATE= 0.
GTP-PRIME=   386083.0
INFL. INDEX= 1.0000  FOR PERIOD   1 TO 30
GROWTH RATE= 1.1000  FOR PERIOD   1 TO  1
             1.0940  FOR PERIOD   2 TO  2
             1.0980  FOR PERIOD   3 TO  3
             1.0950  FOR PERIOD   4 TO  4
             1.0850  FOR PERIOD   5 TO 30
DO YOU WISH TO CONTINUE: YES OR NO


GA INITIAL =       4059.1
GA CURRENT =      44528.4
GTP HISTORICAL =    386083.0
DEPRECIATION RESERVE =    107931.6 ( 27.96%)
ANNUAL DEPRECIATION =     18855.8 (  5.00%)
DO YOU WISH TO HAVE THE VINTAGES PRINTED
DO YOU WANT TO DO ANOTHER SIMULATION:YES OR NO



****************
*  ELG METHOD  *
****************
SRV CURVE= LO.0
AVG LIFE=20.000
MAX LIFE= 30
SALV RATE= 0.
GTP-PRIME=   386083.0
INFL. INDEX= 1.0000  FOR PERIOD   1 TO 30
GROWTH RATE= 1.1000  FOR PERIOD   1 TO  1
             1.0940  FOR PERIOD   2 TO  2
             1.0980  FOR PERIOD   3 TO  3
             1.0950  FOR PERIOD   4 TO  4
             1.0850  FOR PERIOD   5 TO 30
DO YOU WISH TO CONTINUE: YES OR NO


GA INITIAL =       4059.1
GA CURRENT =      44528.4
GTP HISTORICAL =    386083.0
DEPRECIATION RESERVE =    133876.9 ( 34.68%)
ANNUAL DEPRECIATION =     23654.1 (  6.50%)
DO YOU WISH TO HAVE THE VINTAGES PRINTED
DO YOU WANT TO DO ANOTHER SIMULATION:YES OR NO
 STOP
```