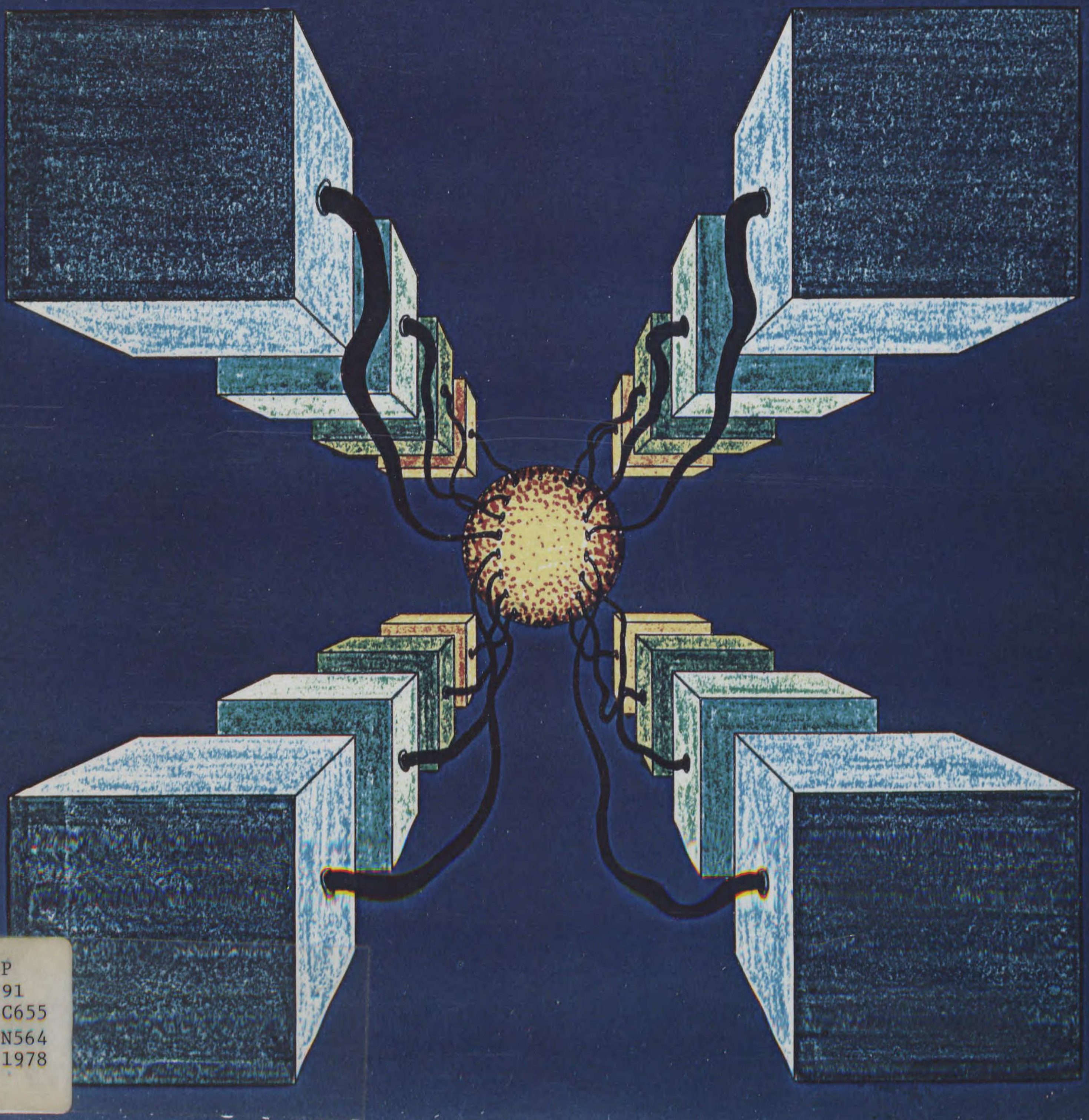
NP & PS PROJECT

ANALYSIS OF INTERREGIONAL POLICY SCENARIOS IN TELECOMMUNICATION

Prepared for and in collaboration with the
Telecommunications Economics Branch, Department of Communications

by
Quasar Systems Ltd, Montreal



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NATIONAL POLICY AND PLANNING SIMULATION

ANALYSIS OF INTERREGIONAL POLICY SCENARIOS IN TELECOMMUNICATION

PREPARED FOR AND IN COLLABORATION WITH THE

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DEPARTMENT OF COMMUNICATIONS

BY

QUASAR SYSTEMS LTD.

MONTREAL

APRIL 30, 1978

FOREWORD

This report contains the results of a study commissioned by the Department of Communications.

The analysis reported herein aimed at answering certain questions related to national telecommunication policy in the context of the institutional evolution now taking place in the Canadian telecommunications industry. A significant facet of the analysis was the use and adaptation of the National Planning and Policy Simulation Model (NPPS) to perform numerical analysis in the areas of study.

ABSTRACT

This document provides a final report on a study whose aims were to analyse certain questions raised by national policy in telecommunications and related to the evolutionary trends in the telecommunications industry.

Specifically, the following questions are considered:

1) What magnitudes of costs and assets are involved in interregional telecommunications and what kinds of system costs could be related to the TCTS portion of the telecommunications markets? A cost and asset separation procedure has been developed and applied to the NPPS network. In addition a new revenue sharing scheme based on the distinction between regional and interregional class assets is investigated.

2) What kinds of effects can be expected if satellite transmission facilities were introduced at competitive prices in southern Canada telecommunications routes? The NPPS model has been used to investigate two specific scenarios for satellite service with regards to the impact on routing of messages in the transmission network.

3) What kinds of analysis can be performed with NPPS to shed some light on the TCTS/CNCP interconnection question, specifically in the area of compensation for loss of business? Certain methods of approaching this problem have been developed and reported on.

RESUME

Ce document constitue le rapport final d'une étude ayant comme objectif l'analyse de certaines politiques nationales en matière de télécommunications dans le contexte de l'évolution que subit cette industrie.

Spécifiquement, les questions suivantes y sont considérées:

1) Quel est l'ordre de grandeur des coûts et actifs impliqués dans les télécommunications interrégionales et quelle partie des coûts pourrait être reliée à la part du marché qu'occupe le Réseau Téléphonique Transcanadien (RTT)?

   Une méthode de séparation des coûts et actifs est élaborée et appliquée au réseau décrit dans le NPPS. Une nouvelle formule de partage des revenus d'appuyant sur la distinction entre actifs à vocation essentiellement régionale et ceux à vocation interrégionale est aussi examinée.

2) Quel impact causerait l'introduction du système de satellite à des prix compétitifs dans le réseau de transmission pour la partie sud du Canada? Deux scénarios sont alors étudiés au moyen du modèle NPPS quant à leurs implications pour l'acheminement géographique des communications.

3) De quelle utilité serait le modèle NPPS en ce qui touche l'analyse des effets de l'interconnexion des réseaux RTT et CNCP, spécialement quant

à l'évaluation de la perte possible pour le RTT.

Certaines méthodes d'approches sont élaborées et décrites dans le rapport.

CONTRIBUTORS

The contributors to this study were as follows:

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1. INTERREGIONAL COMMUNICATIONS ISSUES

In the following section a certain number of issues related to interregional telecommunications policies are analysed. These issues concern, in particular the role of TCTS in interregional telecommunications. The intent is to investigate systems costs and revenues associated with various classes of services and to deduce from these costs and revenues the relative importance of regional long distance services compared to interregional long distance services.

In particular, we postulate the existence of an independent operating body having control over operation and use of interregional telecommunications facilities. This independent operating body could be, in the extreme case, a second tier operator having its own assets and supplying services to the other carriers (a carrier's carrier) in a way similar to the institutional organisation existing in the United States (AT-T long lines). This "operating body" could, on the other hand, be nothing more than a representative mechanism for simulation of regulation in interregional telecommunications in Canada.

In either case, the specific institutional arrangements are not the object of this study. We concentrate rather on the estimation of system costs and revenues that could be associated with this interregional carrier and on a review of the principles which may be used to separate regional long distance and interregional operations.

The following sections contain therefore

- some notes on the theoretical aspects of cost and equipment separation. A review of certain theories of linear programming and game theory is provided to throw some light on the cost allocation methods used.

- an application of one of the basic allocations principles to the TCTS network as represented in the NPPS model.

- a presentation of the results of a numerical analysis and an investigation of the effects of the allocation procedures on various regional companies.

1.1 TWO PRINCIPLES FOR ALLOCATING COSTS

In the following section we consider two methods for the allocation of common costs to users of a facility. The first stems from game theory and the second from linear programming. The game theoretic approach described demonstrates that a usage based allocation (or separation) of common costs fulfills in a decreasing average cost situation the criteria of individual and group rationality, and of Pareto-optimality. This demonstrates that the usage based allocation can be considered as a stable and "equitable" solution to the allocation problem as posed herein.

The second approach uses the principles of linear programming and provides a way of generalising the cost allocation to more complex situations. This latter approach has been included for its possible applications to cost allocations in the context of CNCP/TCTS interconnection but has not been used in the numeric work reported on herein.

1.1.1 GAME THEORETIC APPROACH

In a situation where several different agents produce services independently using some quantity of a common input factor which can be produced more cheaply per unit at larger production levels than at lower levels, there is a definite incentive to enter into common arrangements for the production of this input factor. In the telecommunications industry long distance interregional communications services are produced in precisely this context. That is, long distance communications from various origins to various destinations can be produced using common equipment (an integrated network or a shared repeater) or, if producers can afford the costs, separate devices. In practice the decreasing average costs of transmission of voice circuits provides an incentive for the use of common equipment.

This decreasing average cost situation can be formulated as follows:

$$(1) \quad \sum_{i=1}^{n} C(q_i) > C\left(\sum_{i=1}^{n} q_i\right)$$

where qi is the level of use of a particular device (say circuits in a microwave transmission route) for each of n users i.

Cost separation becomes important in this situation since significant savings can be obtained by each producer (carrier) if he enters into the co-operative arrangement for factor production, but method of determining levels of company contributions to the cost of operating and maintaining the common facility is not immediately clear.

Typically the criterion for allocation of costs might be based on the individual's level of usage multiplied by the average cost per unit at that overall total usage level attained by all users of the device.

This so-called 'usage-based' allocation of annual costs to individual users (which may also be extended to capital costs) is formulated in the following way

$$(2) \qquad e_i = q_i \times \frac{C\left(\sum q_i\right)}{\sum q_i}$$

where ei is the costs allocated to i of the common facility. Note that all costs are covered since

$$\sum e_i = C\left(\sum q_i\right)$$

A brief theoretical note permits us to ascertain that under certain hypotheses this method of cost allocation produces a "Pareto-optimum" cost separation which is in the "core" of the set of all possible cost separations. (The term "core" comes from game theory. Its definition is given in the following paragraphs.)

First, if we define $S \subseteq N$ to be a coalition formed by a subset of the set of producers N, then the value of co-operation within that subset S will be

$$(3) \qquad v(S) = \sum_S C(q_i) - C\left(\sum_S q_i\right)$$

If ki is the price to be charged for use of the common facility by the coalition of all producers then the savings an individual producer i obtains in joining the grand coalition is

$$(4) \qquad x_i = C(q_i) - k_i \qquad i = 1, \ldots, n$$

For a workable and stable grand coalition we require that no group of producers S could pay less for the service of the common facility by forming a subcoalition than the sum of the prices they would have to pay as members of the grand coalition. The same should be true for any sub-coalition of size 1 to N-1.

These principles can be expressed as below

(1) Individual rationality. An individual cannot be induced to join the grand coalition if he can pay less on his own. That is the individual will join the grand coalition if

$$k_i \leq C(q_i)$$

(2) Group Rationality. No coalition (other than the grand coalition) can pay less as a group than the amount they pay as members of the grand coalition.

$$\sum_{S} k_i \leq C\left(\sum_{S} q_i\right) \qquad S \in N$$

(3) Pareto-Optimality. The total cost recovered in the sharing process must cover the total costs of production

$$\sum_{i=1}^{n} k_i = C\left(\sum_{i=1}^{n} q_i\right)$$

These conditions define the subset of all possible cost allocations called the "core".

We now proceed to verify that the usage based allocation proposed in (2) above satisfies these conditions. Working backwards from conditions 4 and 5 we require that

$$\sum_{S} e_i < C\left(\sum q_i\right)$$

(ei is the usage based cost allocation) or

$$\frac{\sum_{S} q_i}{\sum_{N} q_i} \cdot C\left(\sum q_i\right) < C\left(\sum_{S} q_i\right)$$

which, by rewriting gives

$$\frac{C\left(\sum_{N} q_i\right)}{\sum_{N} q_i} < \frac{C\left(\sum_{S} q_i\right)}{\sum_{S} q_i}$$

But this condition simply states that the average cost per unit of production of $\sum_N q_i$ units is less than the average cost of production of $\sum_S q_i$ units for any group S of N. This condition is the diminishing average cost condition or economies of scale, which is generally true in telecommunications.

Hence the usage based cost allocation is an allocation which is in the "core" of all possibe imputations if the production of the product in question is subject to diminishing average costs by quantity. This statement simply means that the usage based cost allocation fulfils the axioms of individual and group rationality and is a Pareto optimal solution to the allocation problem. This cost allocation formula will be applied to the problem of interregional telecommunications supplied by the TCTS.

b) 1.1.2 LINEAR PROGRAMMING APPROACH

In order to establish a cost allocation principle derived from linear programming principles we suppose that the interregional operating body is an entity seeking to maximize its profit without control on the pricing of its product and is required to satisfy the demand for services.

The objective function in this case will be

Maximize Profit = Revenues - Costs

The activity variables in this context may be written as X_{ijkl} (ie the number of circuits to be made available between the origin "i" and the destination "j" passing along the chain "k" on the links "l".)

The previous objective function may then be written as

$$\text{Max } P = R - C = \sum_i \sum_j R_{ij} \cdot \left(\sum_k \sum_\ell X_{ijk\ell} \right) - \sum_\ell C_\ell \left(\sum_i \sum_j \sum_k X_{ijk\ell} \right)$$

This maximization is subject to the demand constraints

$$\sum_k \sum_\ell X_{ijk\ell} \geq D_{ij}$$

and the link capacity constraints

$$\sum_i \sum_j \sum_k X_{ijk\ell} \leq A_\ell$$

The dual variables obtained from the optimal solution of this problem express the total profit variation caused by a marginal variation of demand

$$\frac{\delta P}{\delta D_{ij}} = P^m_{ij}$$

Furthermore if we suppose exogenous fixed revenues (Rij) and demands (Dij) then the above problem becomes simply one of cost minimisation as below

$$\text{Min } C = \sum_\ell C_\ell \left(\sum_i \sum_j \sum_k X_{ijk} \right)$$

subject to the same demand and capacity constraints. In the context of this new problem the dual variables now provide the variation in cost due to a marginal change in demand or capacity. In particular, the duals with respect to demand

(say $\frac{\delta C}{\delta D_{ij}} = C^m_{ij}$)

provide a second method of allocating costs.

In the case of constant marginal costs this provides a cost separation procedure as follows

$$C_{ij} = C_{ij}^{m} \cdot D_{ij}$$

where the allocated cost for use of service from i to j is simply the (constant) marginal cost per unit of service times the level of service.

It is possible to show for constant average cost that this method of separation is identical to the previous method. However when average costs vary this method is an extension of the previous one.

In the next section, the principles of the usage based cost allocation are applied to the carriers and traffic represented in NPPS and numerical results are obtained on this basis.

1.2 USAGE-BASED ALLOCATION OF COSTS APPLIED TO TCTS

The separation or allocation of costs carried out in this section is an allocation of total costs to the categories of traffic as follows

1) Regional interurban
2) Adjacent Member
3) Interregional (TCTS)
4) Canada U.S.A.

The definition of traffic included in each of these categories is given in Figure 1.1

The usage based separation is applied to costs and to assets by breaking the usage of all facilities down into these 4 categories.

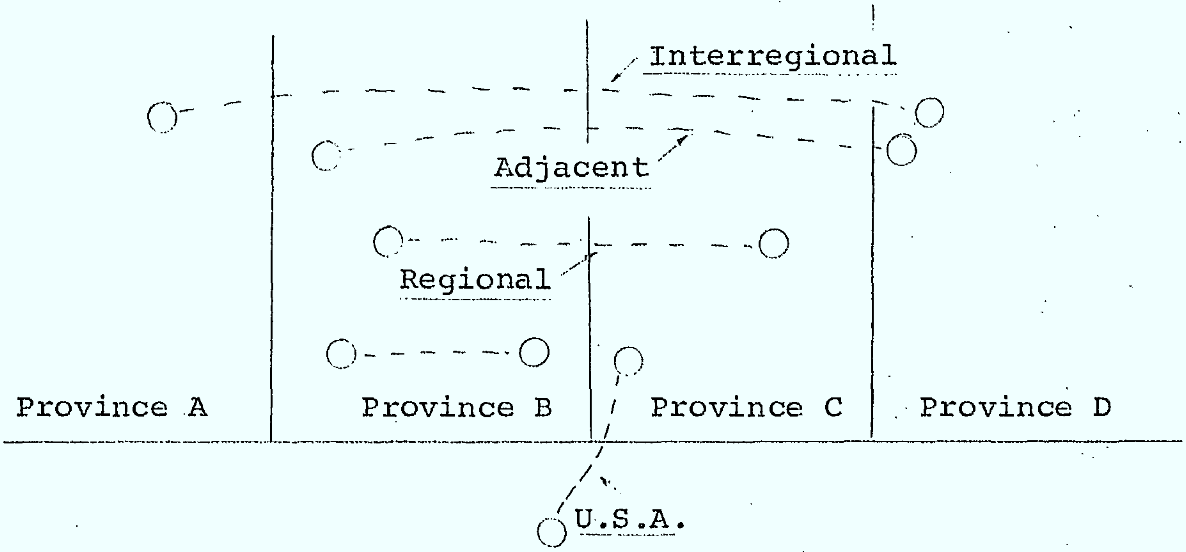
The question of which facilities to consider for a usage based separation of costs has been raised in the context of the role of an interregional operating body. Some justification can be found for the argument that only transmission facility costs should be separated. This point of view follows from the observations that

- there is a tendency (especially in the U.S.) for the development of a multiplicity of different types of traffic which may travel on the same transmission lines

- various data processing firms provide services which encroach on ordinary telecommunications by connecting computers to telecommunications transmission facilities and by handling and processing messages for the computer users

- as more and more varied services are offered to the end user the only common aspect of

FIGURE 1.1



REGIONAL: origin and destination of the traffic are in the same province

ADJACENT: traffic crosses one provincial boundary

INTERREGIONAL: " " two or more " "

U.S.A.: " " U.S.A. "

telecommunications services will be the transmission portion of the service. This is not completely true today since the great majority of telecommunications traffic is processed by the telephone voice switching network. As more and more traffic bypasses this network the "commonality" of voice switching will disappear.

- these observations are true in spite of the fact that in a telephone network switching equipment can be traded off against transmission during network design.

In the allocation of costs obtained herein, however, the principles of usage based separation is applied to all switching and transmission assets in a straight forward way.

The NPPS system identifies usage of the telecommunications transmission network in the following way

1) Estimates of origin-destination traffic are obtained from a gravity model calibrated on a matrix of observed traffic.

2) The origin-destination traffic is assigned to the switched telephone network using the principles of telephone switching and network capacities. This assignment allows for the determination of the composition of end users carried on each switched link (logical connector).

3) The number of switched circuits available in each link of the network is assigned to one or several physical routes between geographical locations. This assignment allows for the determination of the composition of switched links using each transmission link.

4) A combination of assignments obtained in steps 2 and 3 above allows us to determine the breakdown of end user or origin-destination traffic in each physical connection of the network. This so-called end use information is produced by NPPS.

Given this assignment of end users to transmission facilities it is a simple matter to assign each of these users to one of the 4 categories outlined above in order to obtain the usage ratio by category on an element by element basis. A series of computer programs were prepared to perform the computations required herein.

The programs perform the following operations

- calculation of the percentage usage in the 4 traffic categories from the NPPS network usage files. This operation involves summing the usage observed in each traffic stream for the links and nodes involved

- multiplication of the "usage percentages" for the 4 traffic categories by annual costs and by asset values as an element by element basis (this multiplication "assigns" costs and asset values to each category of traffic)

- summing of the assigned costs and assets in each category on a company by company basis

The percentage usage results on an element by element basis are reproduced for reference in Annex 1. The hypotheses used in the generation of this information from NPPS were the following

- network usage is based on peak demands and obtained from the traffic estimation model by using a higher peak to total day ratio for interregional demand than for regional and adjacent partner traffic (procedure recommended in "Development and Empirical Evaluation of Cross Subsidy Tests and Associated Costing Procedures for the NPPS Simulation Model," March 31, 1977 section 3.4.1). These ratios are 7% for regional, 10% for adjacent partner traffic and 12% for interregional traffic

- assignment of traffic to the switching network was performed using the standard switching network database. No redesign of switching links was performed. This database is a representation of 96 of the major Canadian switching nodes

- the multiplex group loading ratio of .75 was used as recommended in the above-mentioned report

- the optimal assignment of circuits to the physical network is based on the marginal cost criterion. Thus the estimate of use of the network is one which is valid for a medium term planning horizon.

FIGURE 1.2

ASSETS BY CATEGORY

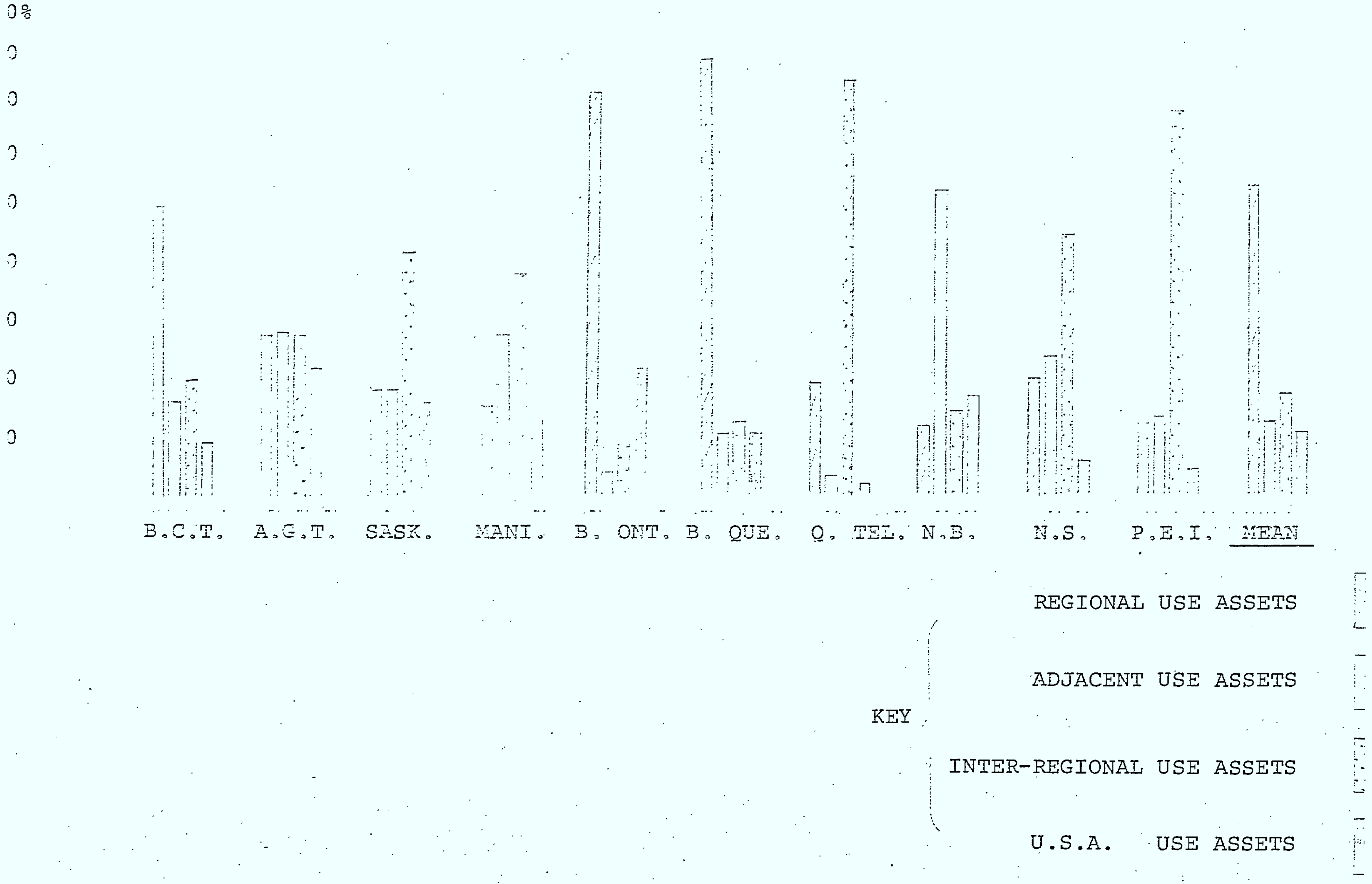


TABLE 1.1

RESULTS OF COST AND ASSET ALLOCATION

TOTAL INCURRED COSTS	REGIONAL		ADJACENT		INTER REGIONAL		U.S.A.		TOTAL
B.C. TEL.	13842271.00	52.3	4507026.00	17.0	5564655.00	21.0	2529422.00	9.6	26444144.00
ALBERTA GOVERNMENT TEL.	5503668.00	28.9	5590238.00	29.3	5526457.00	29.0	2431557.00	12.8	19051920.00
SASKATCHEWAN TELECOM.	2705842.00	19.2	2725989.00	19.3	6218833.00	44.1	2445900.00	17.4	14096564.00
MANITOBA TEL.	1466153.00	16.4	2575226.00	28.8	3600385.00	40.3	1290622.00	14.4	8932386.00
BELL CANADA (ONTARIO)	83081072.00	73.1	4790085.76	4.2	10305495.00	9.1	15483313.00	13.6	113659952.00
BELL CANADA (QUEBEC)	35496608.00	79.2	2934914.00	6.6	3655059.00	8.2	2706061.00	6.0	44792704.00
QUEBEC-TELEPHONE	801556.44	20.0	122565.86	3.1	3020851.00	75.5	56858.73	1.4	4001832.00
NEW BRUNSWICK TELEPHONE	1484550.00	12.3	6669647.00	55.3	1788252.00	14.8	2109058.00	17.5	12051507.00
MARITIMES T.& T. (N.S.)	2373371.00	21.2	2814460.00	25.1	5300306.00	47.3	727453.25	6.5	11215603.00
MARITIMES T.& T. (P.E.I.)	122596.85	12.8	132368.17	13.8	667745.31	69.7	36255.73	3.8	958966.06
TOTAL	146877536.00		32863296.00		45648192.00		29816432.00		255205456.00

TOTAL ASSETS	REGIONAL		ADJACENT		INTER REGIONAL		U.S.A.		TOTAL
B.C. TEL.	55316640.00	52.5	17886064.00	17.0	22050864.00	20.9	10043777.00	9.5	105306144.00
ALBERTA GOVERNMENT TEL.	26633055.00	29.1	25777555.00	28.2	26406876.00	28.9	11628097.00	12.8	91596176.00
SASKATCHEWAN TELECOM.	11280585.00	19.4	11262867.00	19.4	25546016.00	44.0	10026964.00	17.3	58116432.00
MANITOBA TEL.	6886105.00	16.7	11757280.00	27.0	16485774.00	40.0	5702486.00	14.3	41231696.00
BELL CANADA (ONTARIO)	322267136.00	73.2	18435672.00	4.2	37593800.00	9.0	57973904.00	13.6	440267520.00
BELL CANADA (QUEBEC)	138206544.00	79.4	11323040.00	6.5	14115711.00	8.1	10522420.00	6.0	174247696.00
QUEBEC-TELEPHONE	3114855.00	20.3	474113.90	3.1	11513284.00	75.2	217116.25	1.4	15319368.00
NEW BRUNSWICK TELEPHONE	5840726.00	12.4	26187392.00	55.4	6992889.00	14.8	8242066.00	17.4	47273056.00
MARITIMES T.& T. (N.S.)	9403296.00	21.3	11071652.00	25.1	20871526.00	47.2	2856552.00	6.5	44222816.00
MARITIMES T.& T. (P.E.I.)	491950.94	12.8	532028.75	13.8	2684677.00	69.7	145722.94	3.8	3854378.00
TOTAL	579528704.00		135730640.00		186346192.00		119629056.00		1021434368.00

The percentage results shown in Appendix 1 were multiplied respectively by annual costs and asset values for each element of the network in order to obtain the numerical results of cost assignment corresponding to the "averaging" method. In Table 1.1 the numerical results are presented in absolute value and in percentage. In figure 1.2 the same percentage results are shown in the form of a bar chart.

The following observations based on Table 1.1 and Figure 1.2 may be made

- asset and cost separations give essentially the same percentage breakdowns in the 4 categories. This is due to the fact that, in NPPS, and in reality, annual costs are closely related to the replacement value of assets held.

- From the figure 1.2 it is clear that Bell Quebec and Bell Ontario are very autonomous parts of Bell Canada from a traffic point of view, the first having 79.2% of its assets related to regional traffic and the second 73.1%. Some demographic reasons may explain these figures, when one considers how many large traffic generating cities are served by these networks.

- The same is true for B.C. Tel, for which we can add geographic isolation among the reasons for having such a large proportion of regionally oriented assets.

- Other western provinces appear to be more permeable to the external traffic and a significant part of their activities can be associated with transit traffic.

- The results for companies owning only few assets, such as P.E.I. or Q.Tel should be considered with caution because data describing their equipment is not provided to a great level of detail in NPPS.

On the average, we can see that the inter-regional traffic, for which TCTS was created, bears only 18.2% of all assets, and that the total system equipment is used mainly for regional traffic (56.7%).

A second cost assignment method, which corresponds more closely to the physical separation of facilities into classes was investigated. This second method, called the "Equipment Class Assignment Method" is more appropriate for analysis of a case where the interregional carrier is identified separately from the regional carriers.

This second method involves the assignment of each element of the NPPS network to one of two classes, namely regional or interregional. The interregional class of equipment is identified by fixing a lower threshold of usage as follows. If a 60% threshold is chosen then any element having more than 60% of its use devoted to interregional connections would fall into the interregional class. Inversely, any element having less than 60% interregional use (or, in other words more than 100-60 = 40% regional use) falls into the regional class. This method produces a physical assignment of the elements of the NPPS network into two classes which is not the case when the "averaging method" is used.

Furthermore, by performing such an assignment on a regional basis it is possible to identify the different regional impacts of the method.

Calculations based on this method use the same source information as for the previous method and the principal results of this separation method are given in figures 1.3 to 1.16. (numeric results are presented in Annex 2)

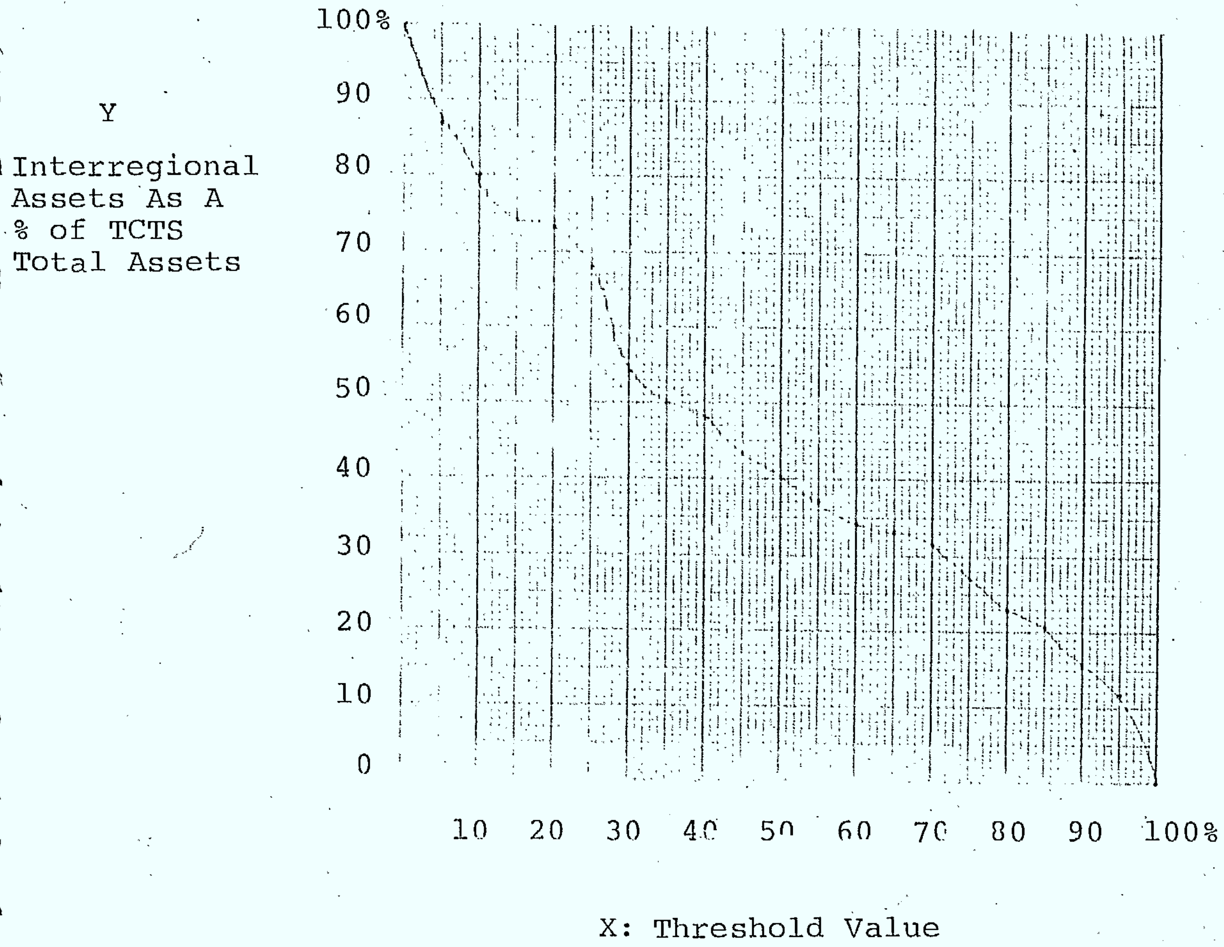
Figure 1.3 gives the level investment in the interregional class (in percentage of total TCTS investment)as a function of the variation of the threshold value. This threshold value is defined as the percentage of interregional use compared to total use on individual elements of the facilities network. The interpretation of the graph for a given point (x,y) is as follows: When the interregional class is defined as all equipment having x% or more interregional use then the total investment in the interregional class will be y% of the total network investment.

We note that the variation in total assets is an approximate linear function of the threshold value used. In particular, as the threshold value diminishes the volume of assets increases in a linear fashion. Figures 1.4 to 1.6 show the results of this separation method for each territory and carrier.

FIGURE 1.3

INTERREGIONAL CARRIER ASSETS

(INTERREGIONAL EQUIPMENT CLASS)



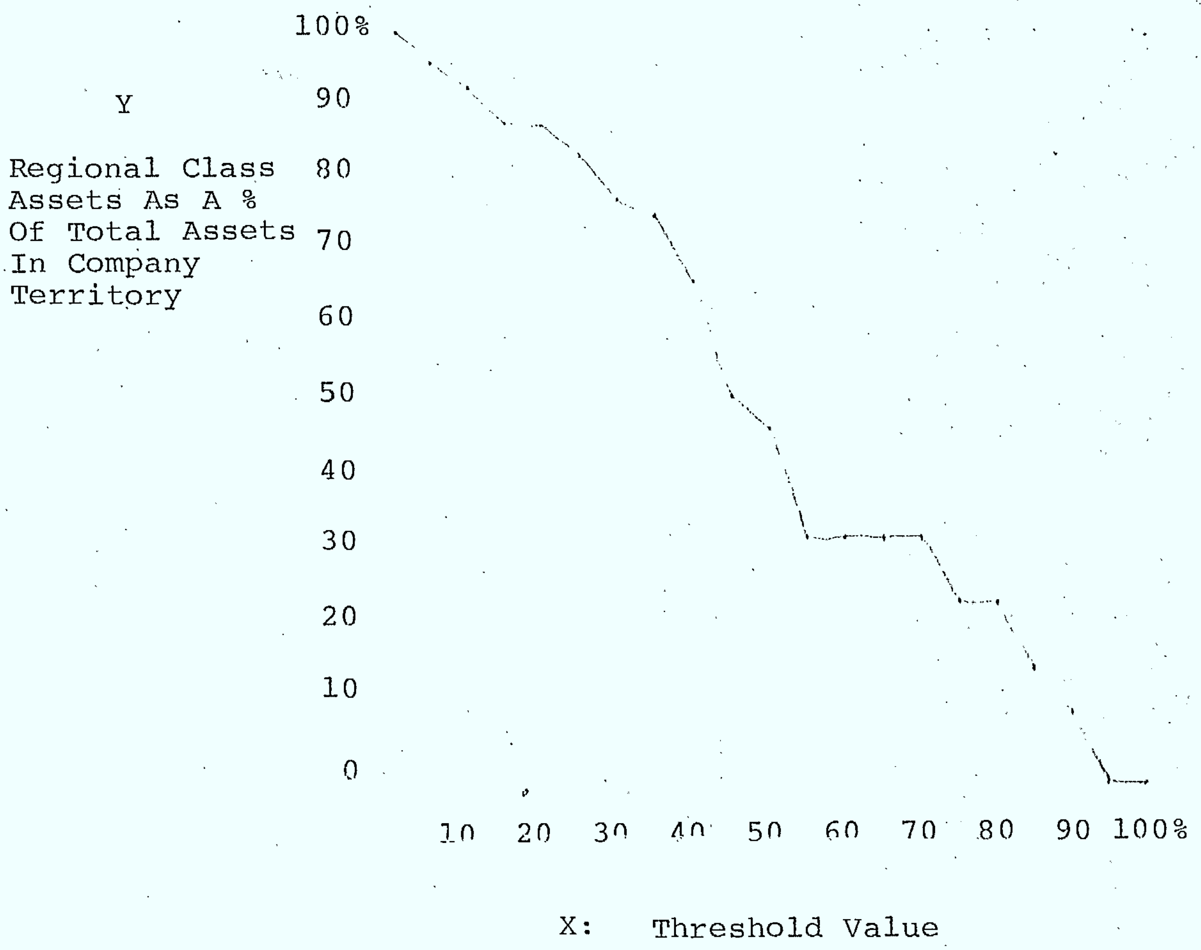
Total TCTS Assets	$1053.9 Millions
Total TCTS Costs	$ 263.5 Millions

$$\text{Threshold Value} = \left(\frac{\text{Interregional Use}}{\text{Interregional + Regional Use}}\right) \text{X100}$$

FIGURE 1.4

B.C. TEL. ASSETS

(REGIONAL EQUIPMENT CLASS)



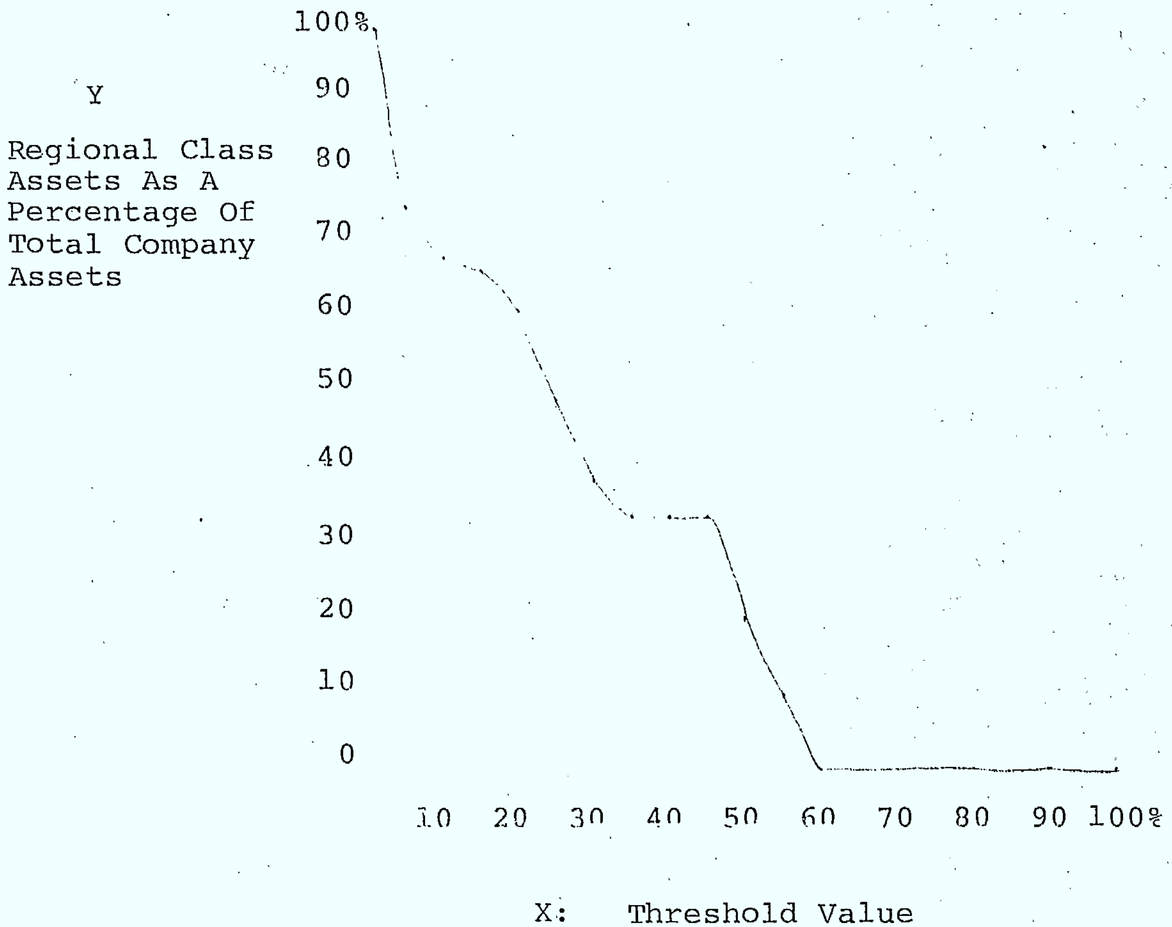
Total Assets Owned By B.C. Tel.:	\$107.9 Millions
Total Related Incurred Costs:	\$ 27.1 Millions

$$\text{Threshold Value} = \left(\frac{\text{Regional use}}{\text{Interregional+Regional Use}}\right) \times 100$$

FIGURE 1.5

ALBERTA GOVERNMENT TEL. ASSET

REGIONAL EQUIPMENT CLASS



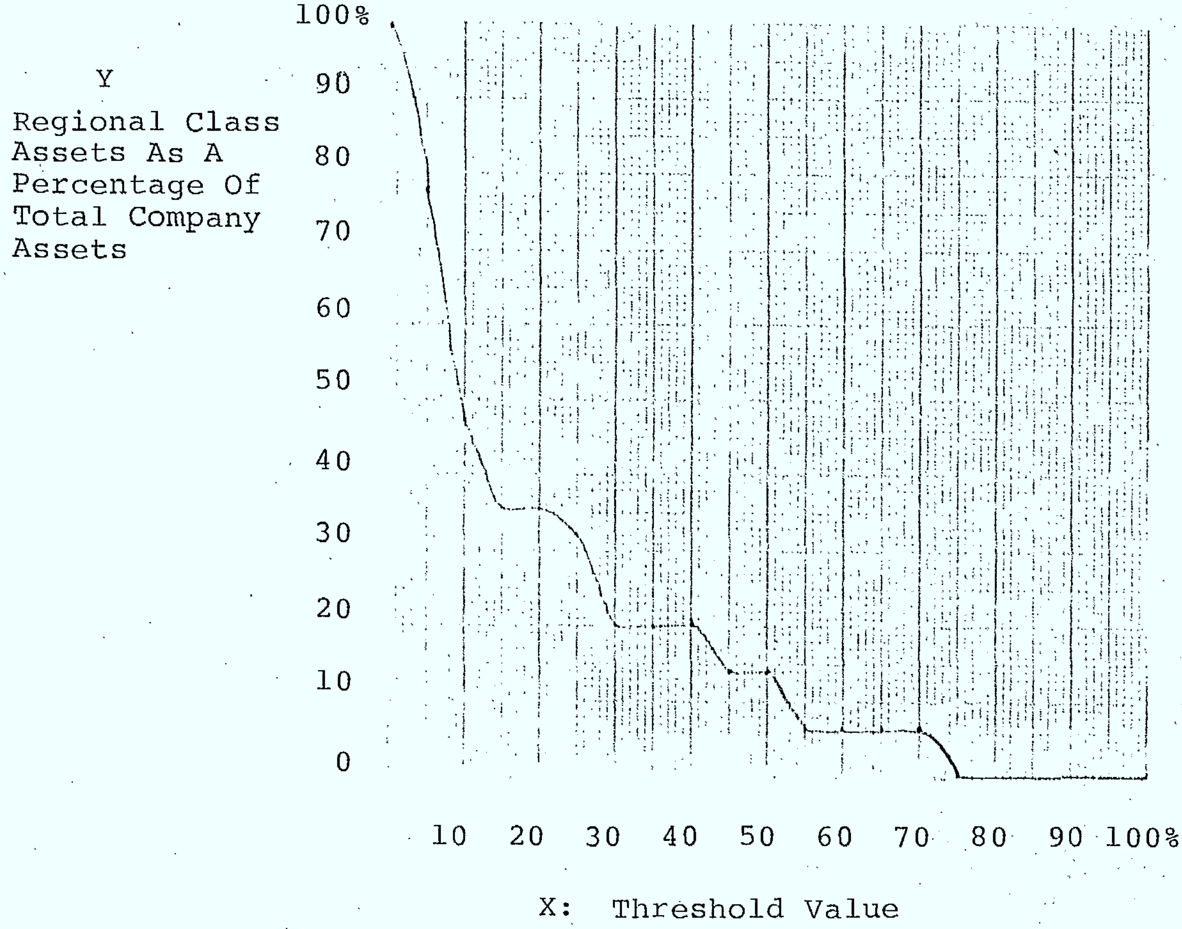
Total Assets Owned By
Alberta Government Tel.: $96.5 Millions
Total Related Incurred
Costs: $20.1 Millions

$$\text{Threshold Value} = \left(\frac{\text{Regional Use}}{\text{Interregional} + \text{Regional Use}} \right) \times 100$$

FIGURE 1.6

SASKATCHEWAN TEL. ASSET

REGIONAL EQUIPMENT CLASS



Total Assets Owned By Saskatchewan Tel.: 58.1 millions

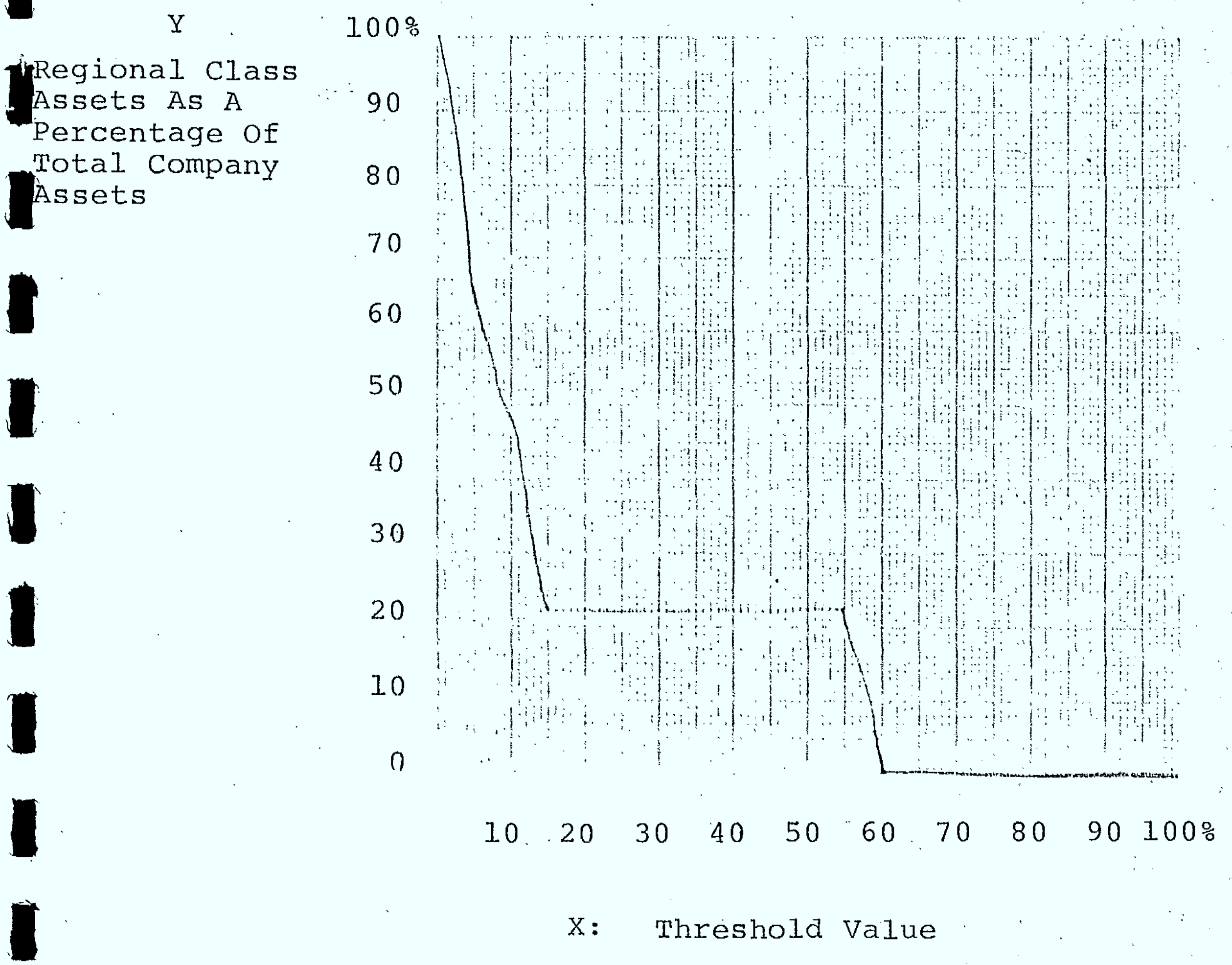
Total Related Incurred Costs: 8.9 millions

$$\text{Threshold value} = \left(\frac{\text{Regional use}}{\text{Interregional + Regional Use}}\right) \times 100$$

FIGURE 1.7

MANITOBA TEL. ASSET

REGIONAL EQUIPMENT CLASS

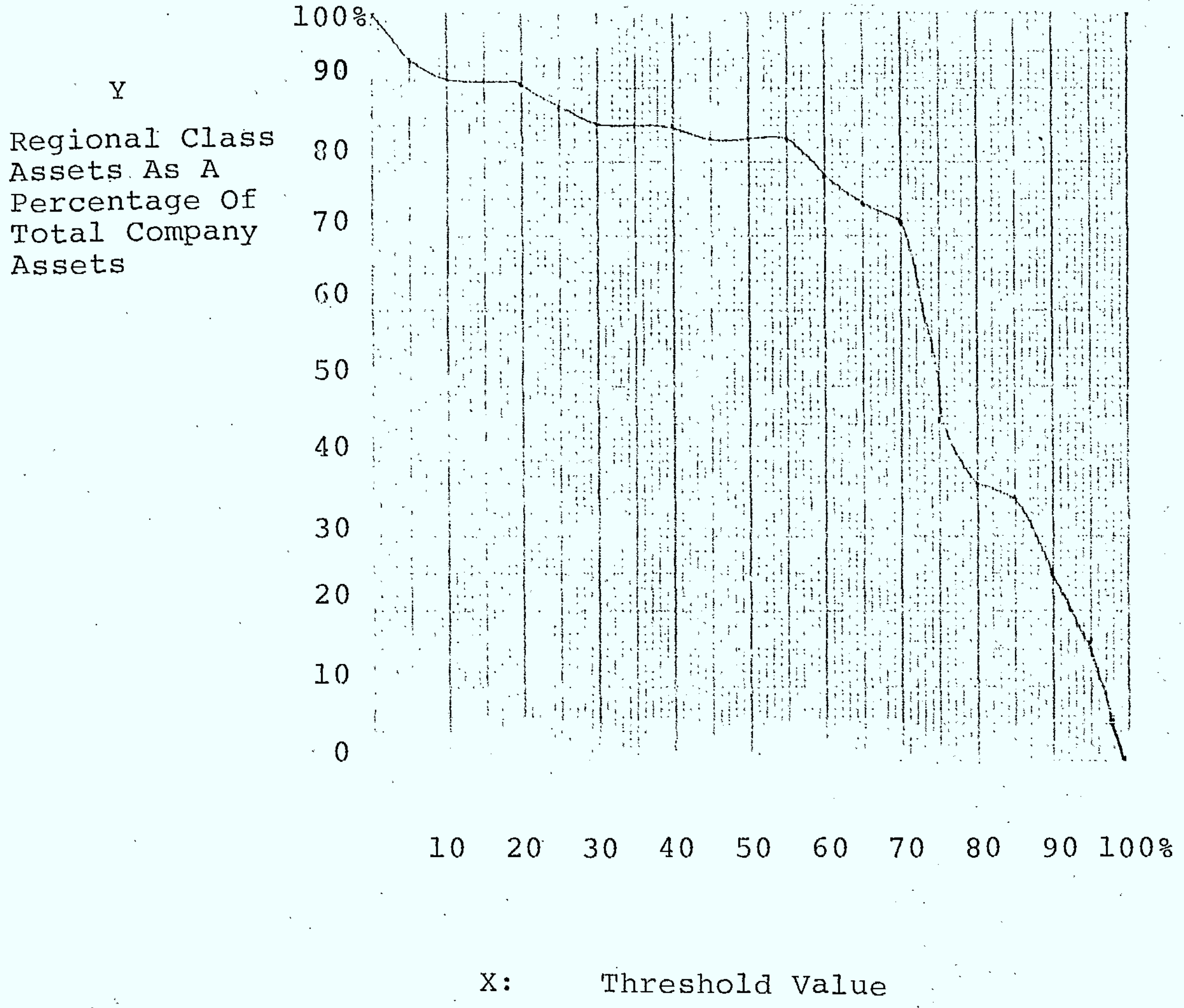


Total Assets Owned By Manitoba Tel.:	41.2 millions
Total Related Incurred Costs:	8.9 millions

FIGURE 1.8

BELL CANADA (ONTARIO) ASSET

REGIONAL EQUIPMENT CLASS



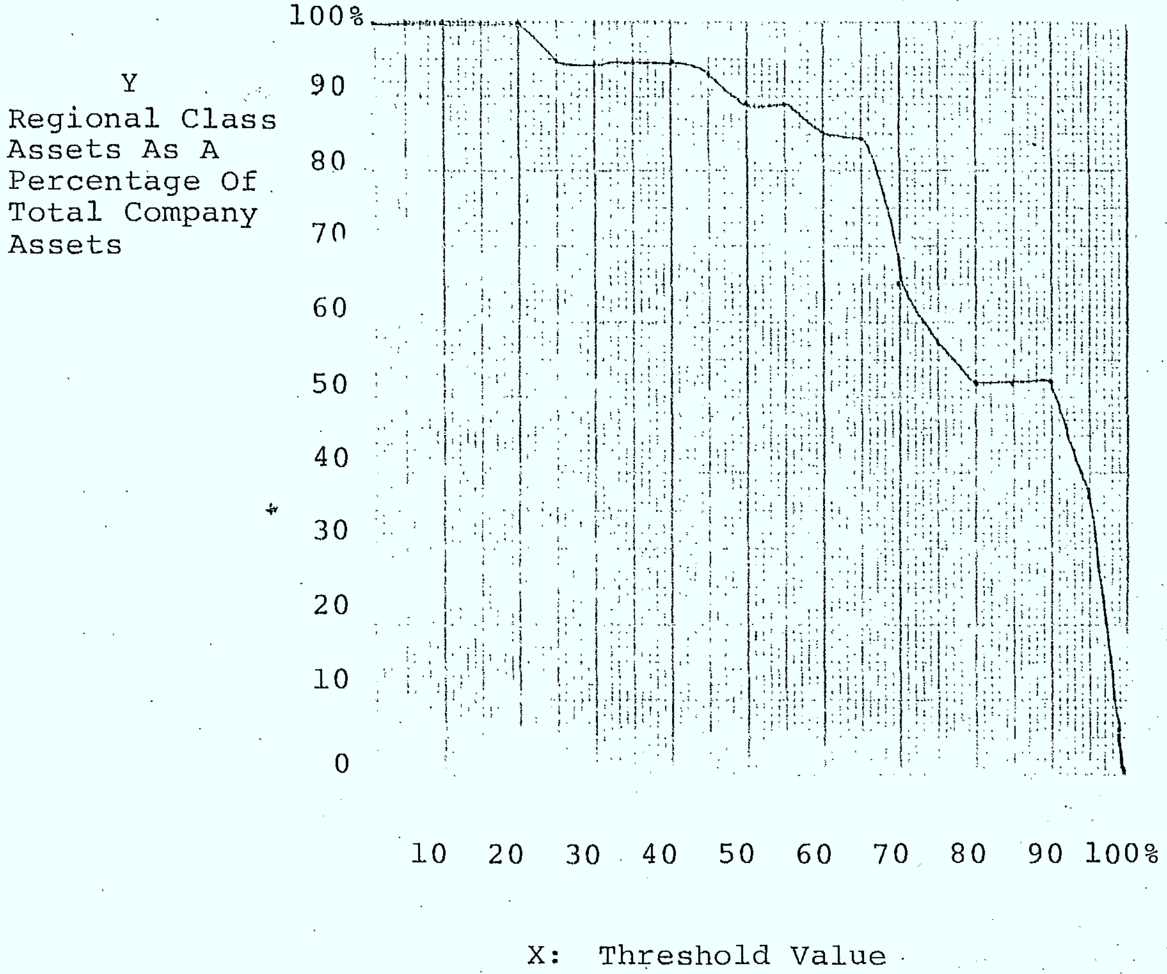
Total Assets Owned by Bell Canada Ont.: 465.2 millions

Total Related Incurred Costs: 120.2 millions

FIGURE 1.9

BELL CANADA (QUEBEC) ASSET

REGIONAL EQUIPMENT CLASS



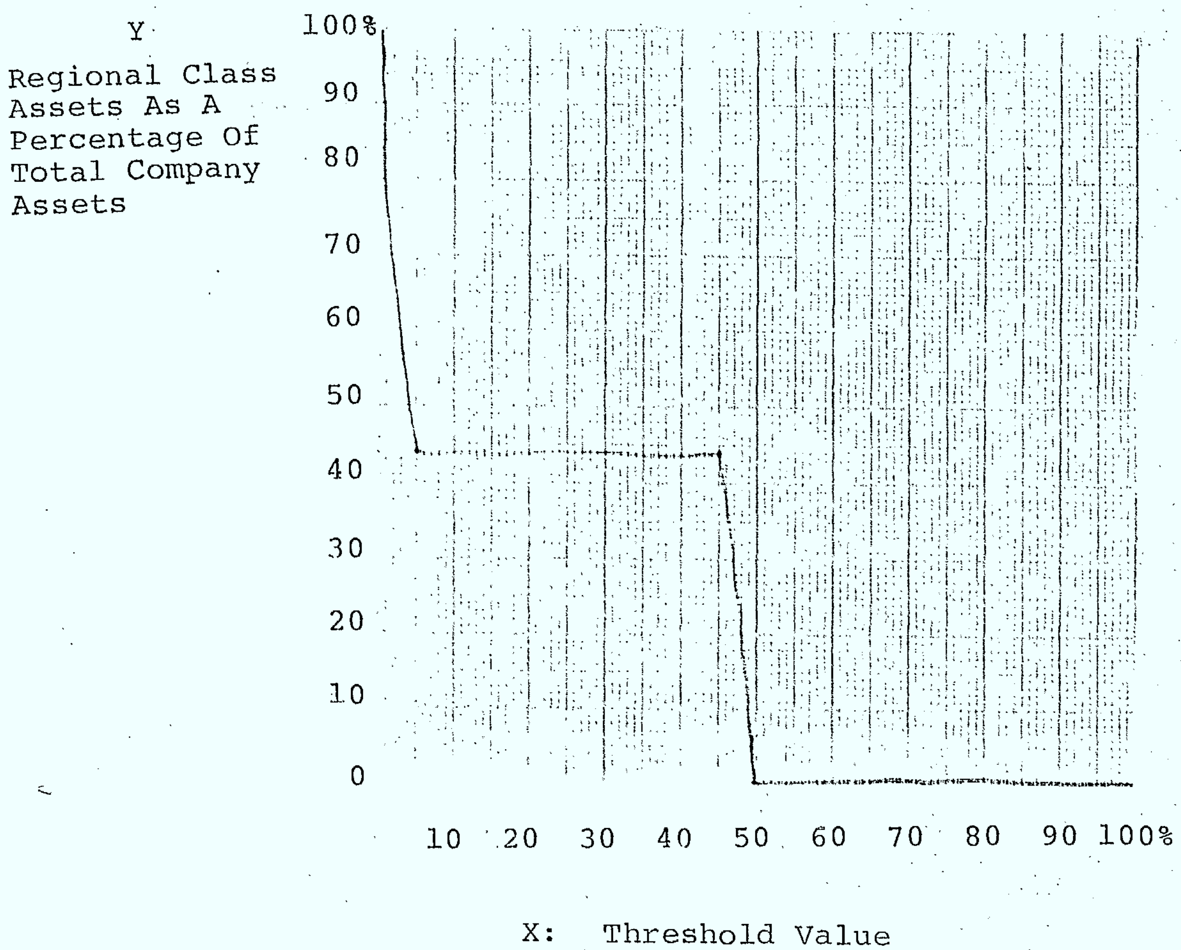
Total Asset Owned by Bell Canada (Que): 174.2 millions

Total Related Incurred Costs: 44.8 millions

FIGURE 1.10

QUEBEC TELEPHONE ASSET

REGIONAL EQUIPMENT CLASS

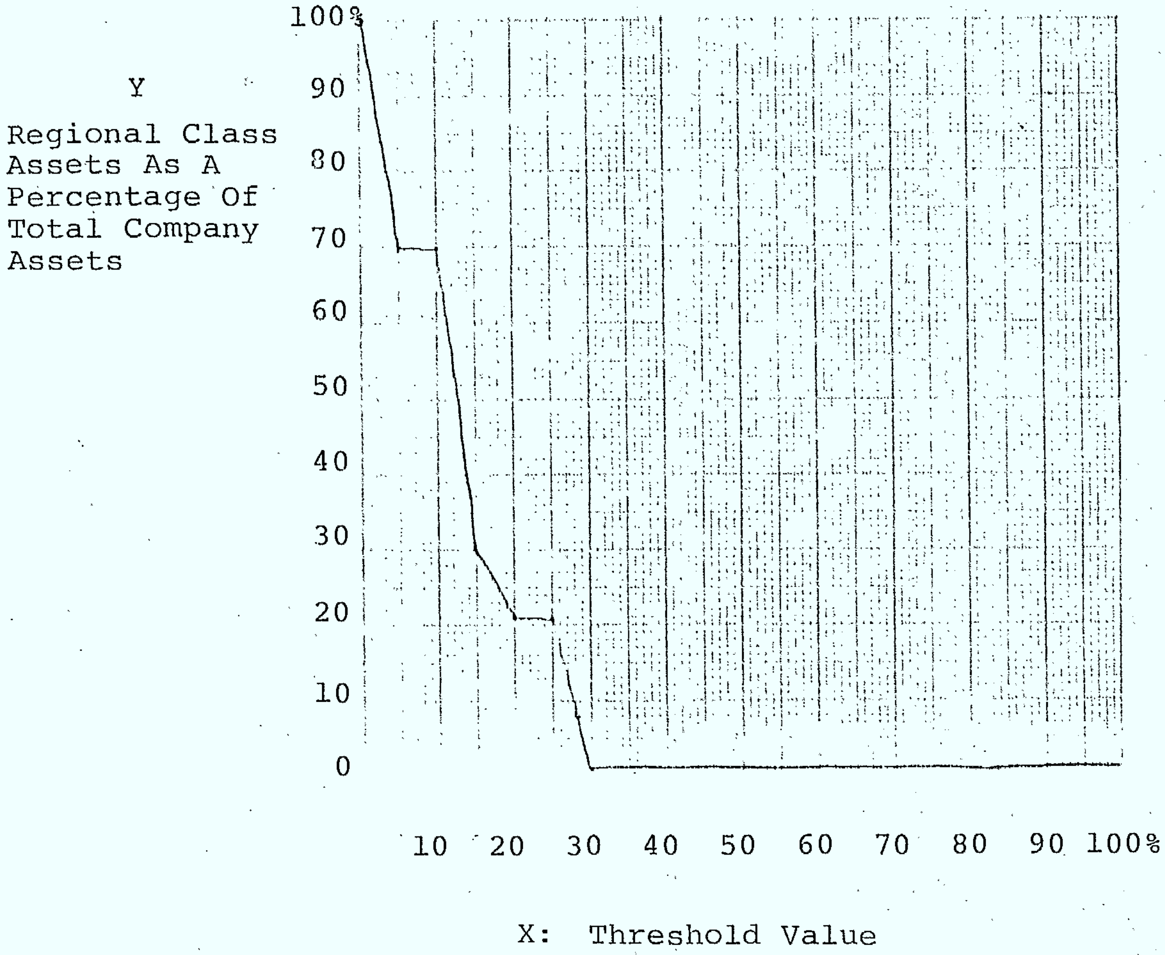


Total Assets Owned by: Quebec Telephone:	15.3 millions
Total Related Incurred Cost:	4.0 millions

FIGURE 1.11

NEW BRUNSWICK TEL. ASSET

REGIONAL EQUIPMENT CLASS

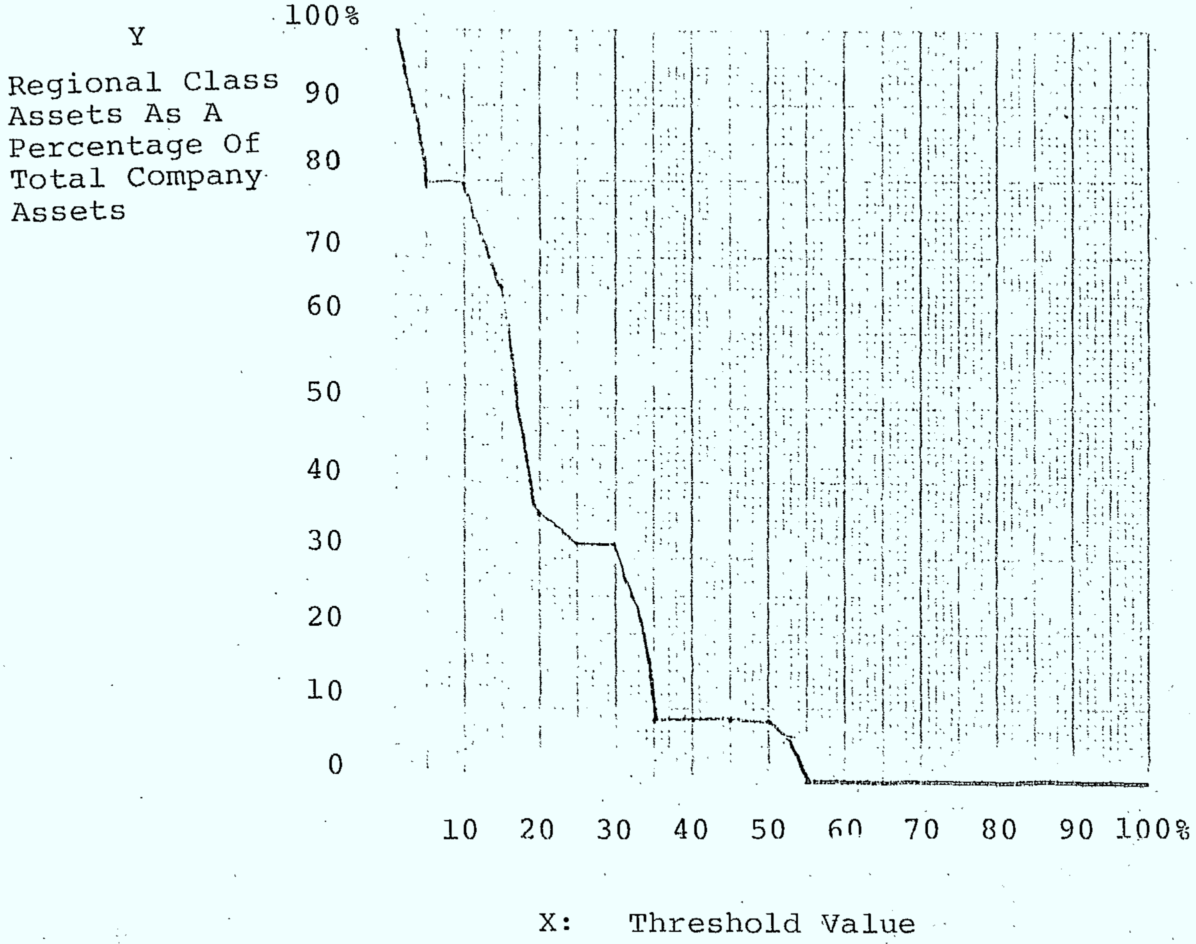


Total Assets Owned by New Brunswick Tel.:	47.3 millions
Total Related Incurred Costs:	12.1 millions

FIGURE 1.12

MARITIMES T. & T. (N.S.) ASSET

REGIONAL EQUIPMENT CLASS

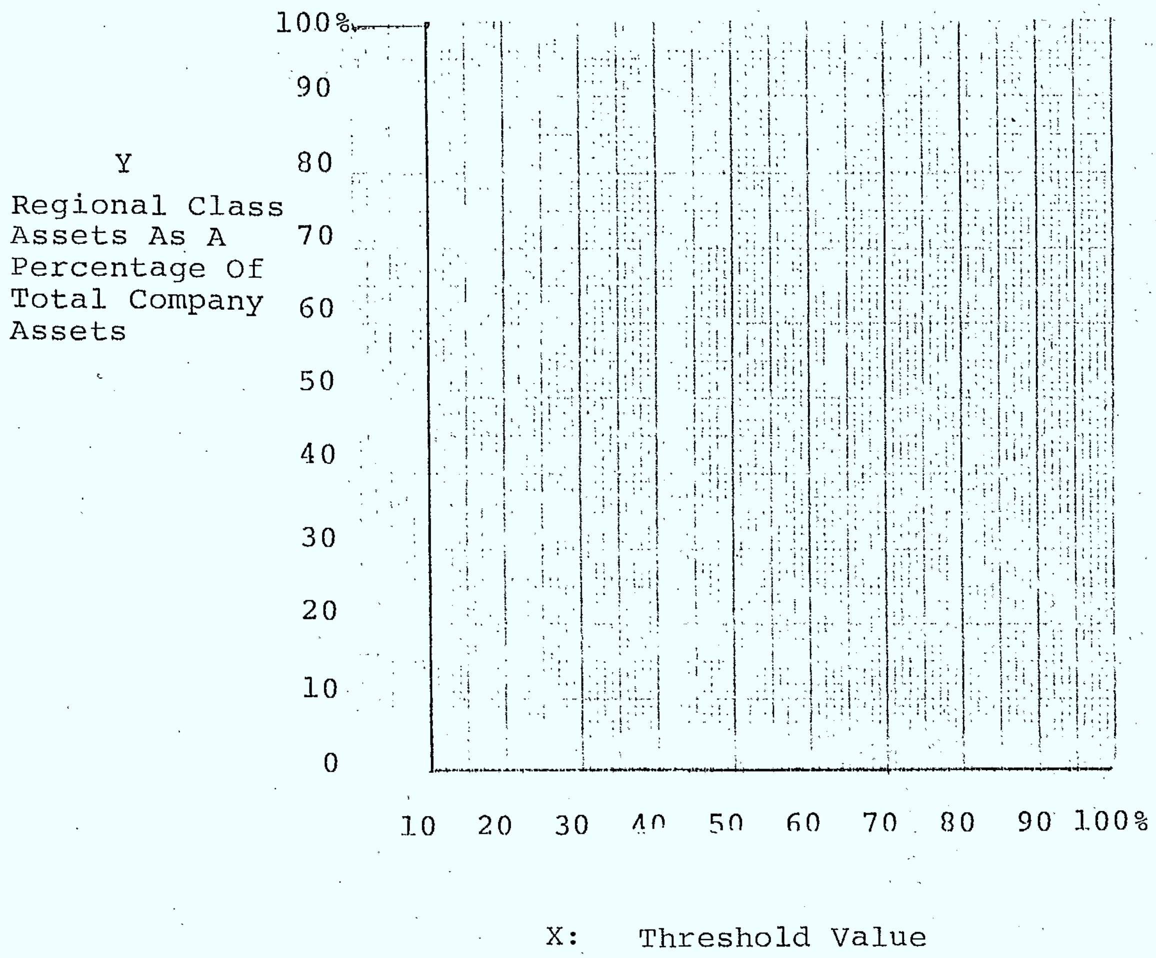


Total Assets Owned by Maritime T. & T.	44.2 millions
Total Related Incurred Costs:	11.2 millions

FIGURE 1.13

MARITIMES T. & T. (P.E.I.) ASSET

REGIONAL EQUIPMENT CLASS



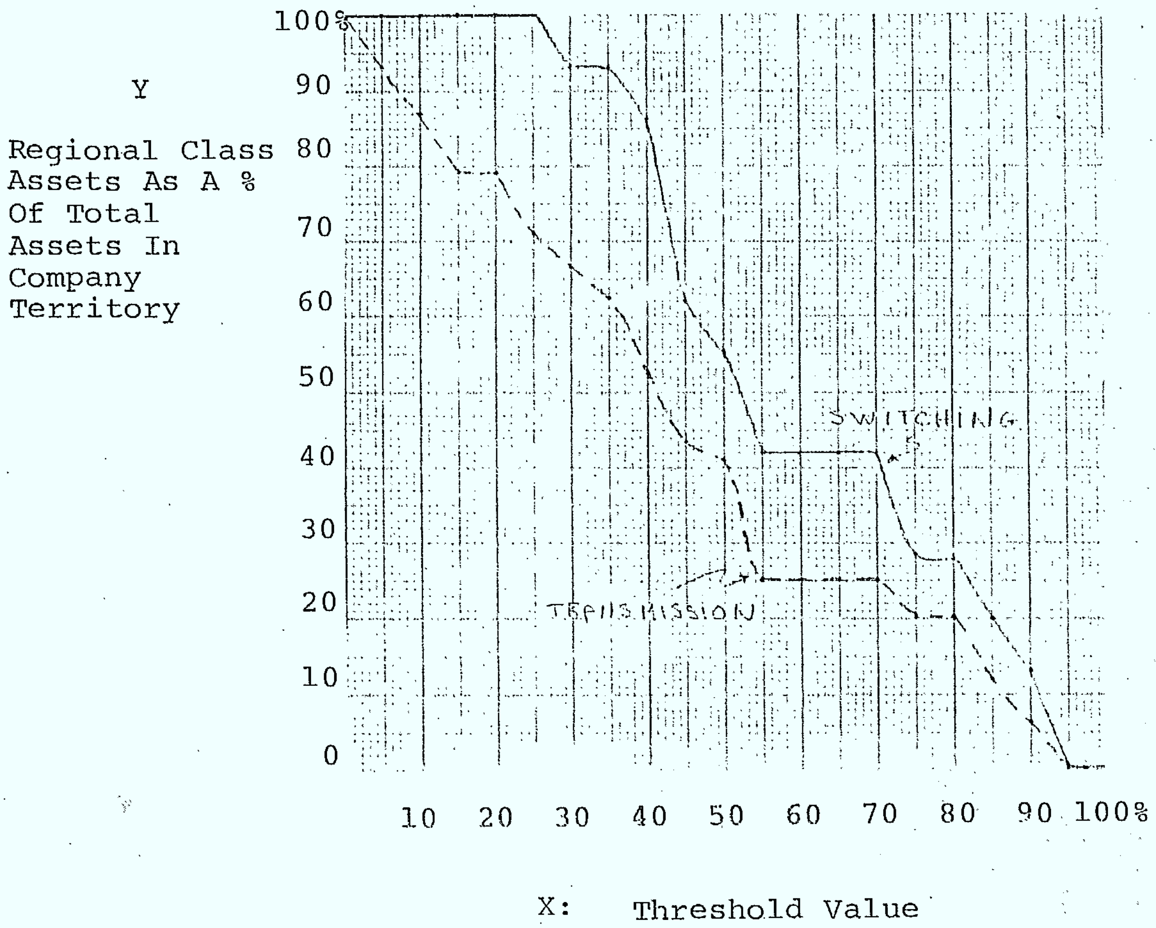
Total Assets Owned by Maritime T. & T. (P.E.I.): 3.9 millions

Total Related Incurred Costs: 1.0 millions

FIGURE 1.14

B.C. TEL. ASSETS

REGIONAL EQUIPMENT CLASS



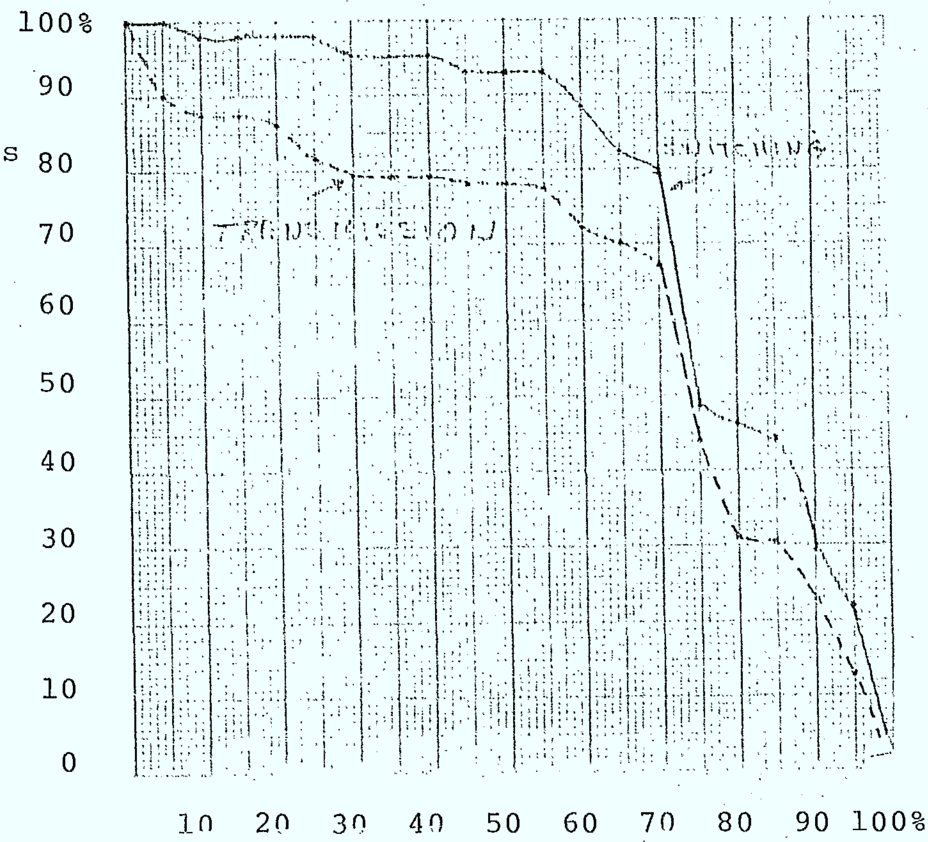
Switching Assets: $44.6 Millions
Transmission Assets: $63.2 Millions

FIGURE 1.15

BELL (ONT.) ASSETS

REGIONAL EQUIPMENT CLASS

Y
Regional Class Assets As A Percentage Of Total Company Assets



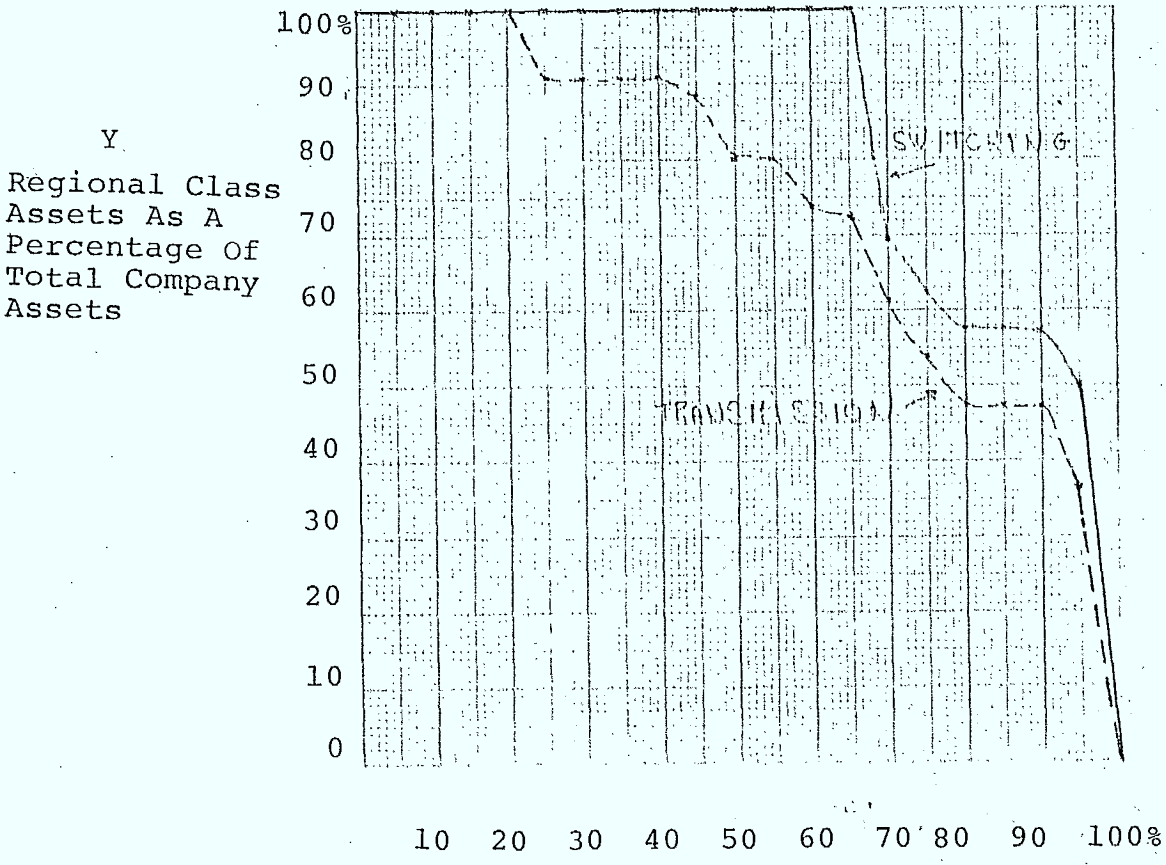
X: Threshold Value

Switching Assets: $158.6 Millions
Transmission Assets: $306.7 Millions

FIGURE 1.16

BELL (QUE.) ASSETS

REGIONAL EQUIPMENT CLASS



X: Threshold Value

Switching Assets: $77.0 Millions
Transmission Assets: $97.2 Millions

On these graphs we present the level of regional class assets (in terms of a percentage of total company assets in each territory) as a function of the threshold value. The threshold value x is defined as the percentage of regional use compared to the total use on individual elements. The interpretation of these figures for a given point (x,y) is as follows: when the regional class of assets is defined as all equipment having x% or more regional use then the total investment in the regional class will by $\bar{y}$% of the total company investment.

These graphs then in effect show that as the definition of regional class assets becomes more and more restrictive (at higher threshold values), the regional class of assets declines to a value of zero. Figures 1.4 through 1.13 show the variation of total assets for each of the territories covered by NPPS. Figures 1.14 through 1.16 show the same assets for B.C. Telephone and Bell Canada (Ontario and Quebec when a distinction is made between switching and transmission assets.

We note from these graphs that the largest companies have most of their assets dedicated to regional traffic. Bell (Ontario) for example has more than 70% of its equipment having in excess of 70% of its use generated by regional traffic.

On the contrary, Saskatchewan Tel has only 20% of its assets which have more than 30% the regional use and no assets (as described in the NPPS model), having percentage of regional use greater than 75%.

When a distinction is made between switching assets and transmission assets as in figures 1.14 to 1.16 the results show that switching is more regional in nature than transmission since at any threshold level proportionally more switching assets fall into the regional class.

1.3 A REVENUE SHARING SCHEME

Based on certain hypotheses as explained below the revenues required by the so-called interregional carrier should receive total revenues to cover the annual incurred costs. As a carriers' carrier, this operating body would receive its revenues directly from the provincial carriers on a basis similar to that proposed for Telesat Canada as a member of TCTS. That is, the members of TCTS would guarantee a rate of return on investment at a certain level to the interprovincial carrier. In this situation, any balance of revenue left over after covering all carriers' incurred costs might be shared only among the regional carriers as end users.

In order to provide an initial estimate of the level of revenues accruing to carriers after sharing under this type of arrangement the following scheme has been investigated.

1. The point of departure is an assignment of all equipment in the NPPS data base to one of two classes - regional or interregional. The assignment used in this analysis is the one ob-

tained by the application of the usage criterion described in section 1.3, and based on a threshold value.

Within the regional class of equipment under this assignment, the usage of facilities is broken down into the 4 categories of regional, adjacent, TCTS and Canada - US usage.

2. The before-settlement revenues calculated by NPPS are pooled and used to cover the incurred costs of all equipment assigned to the interregional class in step 1. This allows for the determination of revenues of the interregional carrier. (Revenues are simply equal to incurred costs).

3. The remainder of revenues, after covering the incurred costs of the interregional carrier are assigned to the regional carriers on a two step plan. First, all costs incurred on regional equipment are covered out of the balance revenue. Secondly, if a final balance remains after covering these regional costs, this balance of revenue is assigned to each of the regional carriers on the basis of their contribution to the provision of interregional services.

The process described above can be formulated in a precise way as follows:

Let Ri: before settlement revenues as collected by each regional carrier.

C1i: annual incurred costs of the regional carriers i on the regional class of equipment.

C2i: annual incurred costs of the regional carriers on the interregional class of equipment.

The costs incurred in total (on the interregional class of equipment) are

$$\sum_{i} C_{2i}$$

The balance of revenue for distribution to the regional class equipment is

$$B_1 = \sum_{i=1}^{n} R_i - \sum_{i=1}^{n} C_{2i}$$

From the balance of revenue B1, each regional carrier is assigned revenues to cover the annual incurred costs.

The balance of revenue after this operation is:

$$B_2 = B_1 - \sum_{i=1}^{n} C_{1i}$$

If B2 is positive, this balance is assigned to the regional carriers on the basis of each regional carriers' contribution to interregional service on regional class equipment.

Let Cli be broken down into the four incurred cost components:

Cli1 - Cost incurred on the regional class of equipment for regional usage.

Cli2 - Cost incurred on the regional class of equipment for regional usage.

Cli3 - Cost incurred on the regional class of of equipment for interregional usage (note that interregional traffic at low levels will continue to be present on the regional class of equipment).

Cli4 - Cost incurred on the regional class of equipment for Canada-US usage.

These incurred cost components may be used as indicators of the degree of contribution of regional class equipment to interregional service.

Hence the final balance of revenue is allocated to regional carriers on the following basis:

$$B_2 \cdot \frac{C_{1i3}}{\sum_{i=1} C_{1i3}}$$

The total revenue accruing to the regional carrier is then:

$$R'_i = C_{1i} + \frac{B_2 \cdot C_{1i3}}{\sum_{i=1}^{n} C_{1i3}}$$

or

$$R'_i = C_{1i1} + C_{1i2} + C_{1i3}\left(1 + \frac{B_2}{\sum C_{1i3}}\right) + C_{1i4}$$

The principle has been applied to the results of the NPPS simulation to ascertain the effect of this type of settlement scheme on the various partners of TCTS compared to the application of the ordinary TCTS scheme without an interregional operating body.

One of the shortcomings of the application of this scheme using NPPS is as follows:

- Normally, an interregional operating body would experience incurred costs across the country in the same way. That is, the financial structure or financing mechanisms would lead to standard cost formulae for all types of equipment. However, in NPPS it is not possible to distinguish, in the costing process, between regional class equipment and interregional class equipment and therefore the annual incurred costs computed by the model for interregional class equipment varies from region to region in the same way as regional costs vary. It is expected that this variation would not introduce a large bias in the results since the incurred costs to assets ratio varies only by small amounts from region to region.

Tables 1.2 and 1.3 contain numerical results based on the revenue sharing scheme proposed above.

In table 1.2 the interregional class of equipment includes only those facilities having at least 75% interregional usage. In table 1.3 the interregional class includes all equipment having at least 40% interregional usage.

In each table the rows are defined as follows:

A: total pre-settlement revenue as produced by NPPS program REVSHR.

B: Annual costs for the Interregional class of equipment (source NPPS program BCPR8).

C: Balance B1 as defined above.

D: Annual costs for the regional class of equipment (as broken down by NPPS program BCPR8).

E: Balance B2 as defined above.

F: Percentage share of B2 for each partner based on his proportional contribution to the carrying of interregional traffic on the regional class of equipment. Zeroes encountered in Table 1.3 simply indicate that the criteria used for defining the interregional class is so restrictive as to imply an empty regional class of equipment in the region.

G. Absolute share of B2 obtained by applying the percentages of F to the Balance B2.

H. Total revenues after settlement using the regional/interregional class method represented in each region by the sum of costs on each class of equipment plus the prorated share of the final balance.

I. Total revenues after settlement when the regional class of equipment is excluded (as when assuming the presence of an interregional carrier).

J. Comparative results from the NPPS usage based revenue sharing scheme.

K. Net differences between the present method and the NPPS usage based method. A positive sign means that the carrier gains revenues under the present scheme relative to the NPPS usage based scheme.

TABLE 1.2 RESULTS OF REVENUE SHARING SCHEME.

INTERREGIONAL CLASS: EQUIPMENT USED 75% OR MORE BY INTERREGIONAL TRAFFIC.

	B.C. TEL.	ALTA.	SASK.	MANI	B.ONT.	B.QUE.	Q.TEL.	N.B.	N.S.	P.E.I.	TOTALS
A. Total Pre-Settlement Rev.											$475,644.
B. Costs of Interregional Class Equip.	4685	10169	9628	6975	15459	2315	2260	9525	7626	958	$(69,600)
C. Balance (B1)											$406,044
D. Cost on Regional Class Equipment	13335	4597	2064	1091	81948	34981	802	682	1372	0	$(140871)
E. Balance (B2)											$265,173
F. % for share of B2	.1736	.1020	.0460	.0166	.4368	.1434	.0039	.0353	.0424	0	1.00
G. Share of B2	46034	27047	12198	4402	115828	38026	1034	9361	11243	0	$(265173)
H. Total Revenue after settlement (B)+(D)+(G)	64054	41813	23890	12468	213235	75322	4096	19568	20241	958	$475,635.
I. Revenues for regional carriers (D) + (G)	59369	31644	14262	5493	197776	73007	1836	10043	12615	0	$406,044
J. NPPS Usage based Scheme results	29960	22402	13878	14198	376,851		2102	9302	6941		$475,644.
K. Net difference (H)-(J)	+ 34094	+ 19411	− 10012	− 1730	− 88,294		+ 1994	+ 10266	+ 14258		0

TABLE 1.3 RESULTS OF REVENUE SHARING SCHEME.

INTERREGIONAL CLASS: EQUIPMENT USED 40% OR MORE BY INTERREGIONAL TRAFFIC.

	B.C.TEL	ALTA.	SASK.	MANI.	B.ONT.	B.QUE.	Q.TEL.	N.B.	N.S.	P.E.I.	TOTALS
A. Total Pre-settlement rev.											$475,644.
B. Cost of Interregional Class Equip.	18359	19907	13180	8932	26892	6659	4002	12052	11216	959	(122,156)
C. Balance (B1)											$353,488
D. Cost on regional class equipment.	7303	195	687	0	76497	32718	0	0	0	0	(117,400)
E. Balance (B2)											$236,088
F. % for share of B2	.060	0	.0096	0	.7041	.2263	0	0	0	0	1.00
G. Share of B2	14165	0	2266	0	166229	53426	0	0	0	0	(236,088)
H. Total revenue after settlement (B)+(D)+(G)	39827	20102	16133	8932	269618	92803	4002	12052	11216	959	475,644
I. Revenues for regional carriers (D)+(G)	21468	195	2953	0	242726	86144	0	0	0	0	353,488
J. NPPS Usage based scheme results	29960	22402	13878	14198	376,851		2102	9302	6941		475,644
K. Net difference (H)−(J)	+ 9867	− 2300	− 2255	− 5266	− 14,430		+ 1900	+ 2750	+ 5234		0

We may make the following observations about these results:

- The current method of revenue sharing shifts Bell Canada revenues to the other carriers. A smaller the interregional class implies a larger the shift in revenue. This result is due to the fact that Bell Canada's contribution to interregional traffic on regional class equipment is low. This, in turn, reflects the relatively large volume of regional traffic handled by Bell Canada compared to other carriers.

- A relatively large amount of revenue is distributed as a final balance (B2). In both tables roughly half the revenues are distributed at this step. This means that the revenue separation method is sensitive to the criterion chosen for the distribution of the final balance of revenue. Note that if the final balance is distributed proportionally to total assets then this sharing method is identical to the "TCTS Method" used in NPPS.

2. SATELLITE ISSUES.

In the following section, we discuss several issues raised by the introduction of satellite transmission services more intensively into telecommunications in Canada's populated areas. In the context of NPPS, it is of interest to investigate the effect of the introduction of satellite services on the flow of messages through the telecommunications network and on the relative financial positions of the terrestrial carriers of TCTS. In order to perform this analysis with the NPPS system, it will be necessary to elaborate certain scenarios related to the cost and configuration of satellite services in southern Canada, and it will be necessary to accept certain limitations imposed on the analysis by the NPPS model structure.

In the subsequent section, we consider:

- general practical and theoretical considerations about the routing results when a new link is introduced.

- two reasonable scenarios for the introduction of satellite services and for each scenario the effect on the introduction of satellite on routing of messages and the subsequent effects on costs and use of equipment in the terrestrial network.

2.1 SOME GENERAL CONSIDERATIONS REGARDING THE NETWORK ROUTING PROBLEM.

In the NPPS module CIRRES, the allocation of switched and private line connections to the transmission network is done on the basis of cost criteria. In fact, in view of the general excess capacity available in the network and of its east-west orientation, the number of realistic alternate routes is limited.

In particular, if we introduce a new connection from say Vancouver to Toronto at some specific cost the behaviour of the routing solution will respond as shown in Figure 2.1 for various cost levels.

We see that for unit prices below the level B, (at A for example) the number of circuits routed via the satellite will stay at some constant maximum level C. This level is determined by the structure of network and the relationship of capacities to demands but will be, in general, equal to either

- the maximum usable capacity of the satellite connection itself;

- the maximum capacity of the access network servicing the earth station.

If the limiting constraint is satellite capacity itself then the dual variable of the solution related to the capacity constraint will be positive and the effect of increased capacity on the satellite will be further reductions in cost in the overall allocation. If the limiting constraint is the capacity of the access network then the value of extra capacity on the satellite will be null in the overall cost minimization.

Except for a special case considered below there will be a range of costs (between B and D in figure 2.1) for which the total use of the satellite will fall off progressively as per unit price increases. As the price increases, the first users to abandon satellite service would seem to be those located furthest away (in terms of terrestrial costs) from the earth station. However, this statement is not, in fact, rigourously true. More precisely, as costs increase for satellite service, the users who abandon the service will be those whose total route costs can be reduced by rerouting through terrestrial facilities (which is not the same as the preceeding statement). In figure 2.2 a simple example helps to illustrate this fact.

FIGURE 2.1

EFFECT OF COST OF SATELLITE SERVICES ON ITS USE

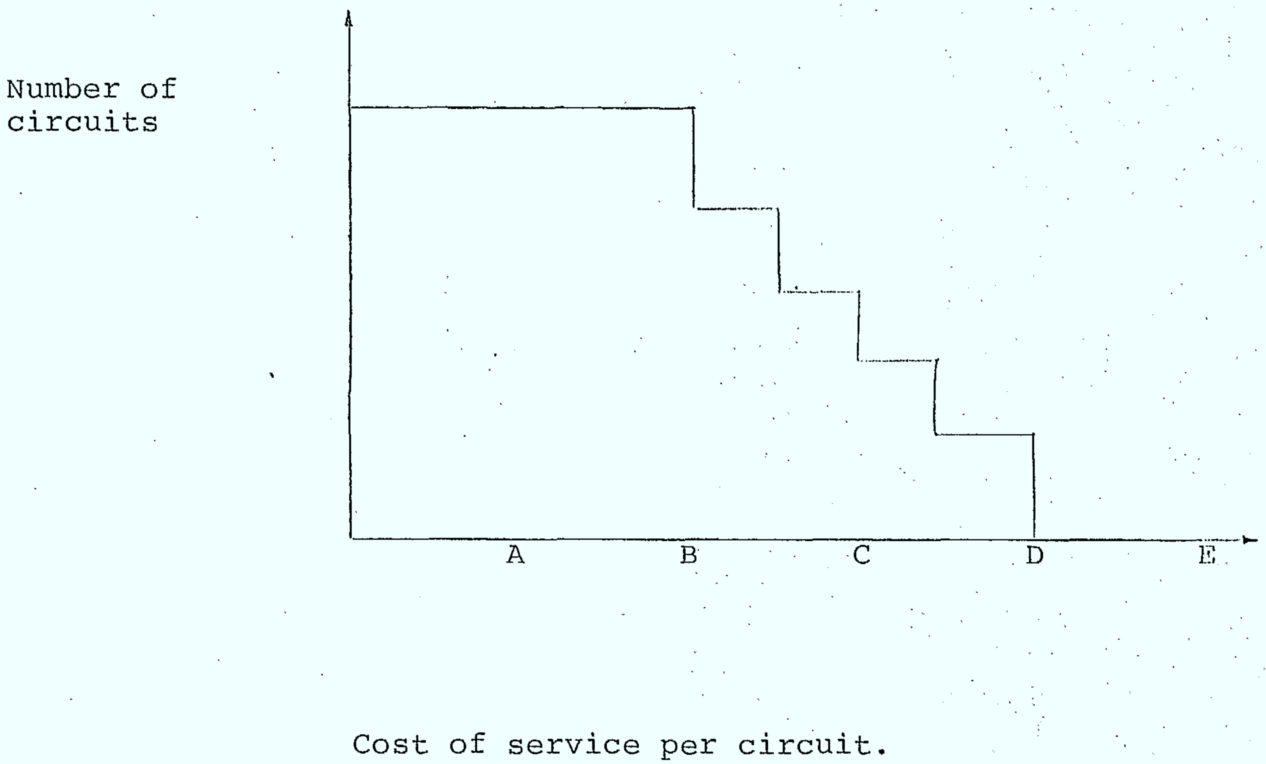
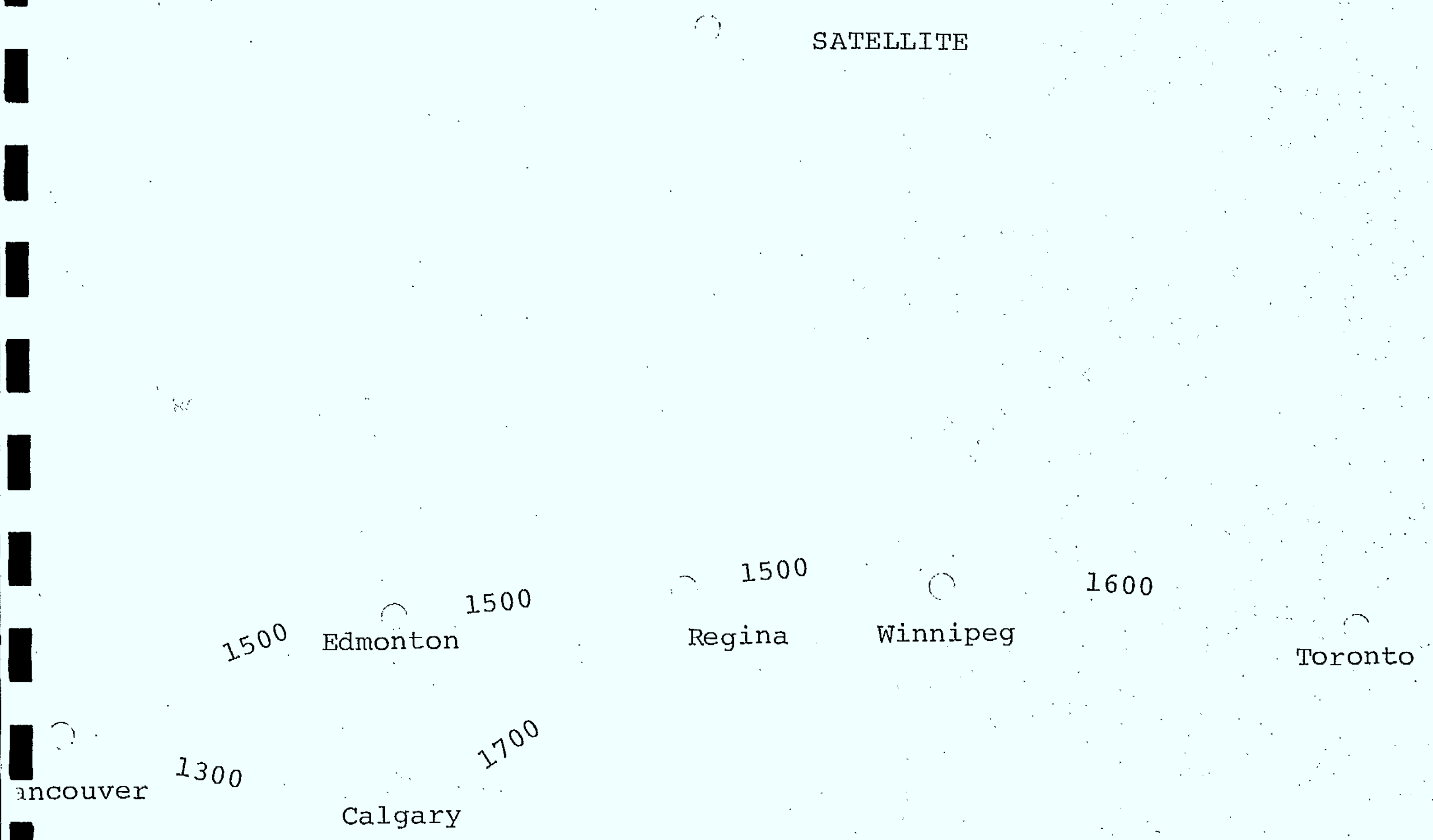


FIGURE 2.2

ROUTING BY SATELLITE. A SIMPLE EXAMPLE



Costs in $ per circuit for terrestrial routes

In this example, if the cost of satellite transmission from Vancouver to Toronto (ignoring capacity constraints) takes the values 500, 3000, and 6000 the table 2.1 shows the costs of alternate routings by demand pair. As shown when the price increases from $500. to $3000. the Vancouver-Winnipeg link reverts to terrestrial routing, but the Edmonton-Toronto route does not. It is easy to see from this example that, ignoring capacity constraints the price above which the satellite link will be unused is the price of the alternate terrestrial route (Vancouver-Toronto-$6100.). This price level corresponds to D in figure 2.1. The price level of B in figure 2.1 is more difficult to evaluate and depends in fact on the network capacity constraints. This argument demonstrates in fact that there is no single price above which the satellite is saturated and below which it is unused. The drop off in use will be progressive in almost all cases.

More specifically, B = D when a single demand pair has a large enough demand to saturate the satellite capacity alone and is also the most sensitive to reduction of price below the level of D (for example the Vancouver-Toronto demand pair). Since this is unlikely to occur, we are virtually assured that usage of the satellite will grow progressively as the price declines below D.

The estimation of the level of B is of interest to us since this is the price at which demand for service (function of the price) just meets the supply limit imposed by network constraints.

The estimation of B in the TCTS network is considered in the following sections.

TABLE 2.1 COSTS OF ALTERNATE ROUTES BY DEMAND PAIR.

DEMAND PAIR	TERRESTRIAL ROUTE	ROUTE COSTS VIA SATELLITE		
		LINK COSTS		
		$500.	$3000.	$6200.
Vancouver-Calgary	1300	----		
-Edmonton	1500	----		
-Regina	3000	3600	6100	
-Winnipeg	4500	2100*	4600	
-Toronto	6100	500*	3000*	6200
Edmonton-Regina	1500	----		
-Winnipeg	3000	3700	6200	
-Toronto	4600	2000*	4500*	7700
Calgary-Regina	1700	----		
-Winnipeg	3200	3400	5900	
-Toronto	4800	1800*	4300*	7500
Regina-Winnipeg	1500	----		
-Toronto	3100	3500	6000	

* connection cheaper via satellite.

2.2.1 RESULTS FOR SCENARIO I

In the preparation of scenario I, the following set-up was required in the model

- addition of the satellite connection between Vancouver and Toronto in the transmission links database (File TTRAN1)
- addition of the price for circuits routed by satellite (manually) into the link cost file (CLINK). This operation provides a link cost parameter for use in the routing algorithm.
- execution of programs SETUP, REDUC, CIRRES and EXPAN in batch mode
- execution of DKODER to extract the detailed information required for analysis of switched circuits allocated to different routes and cuts of the transmission network

Based on the estimate of the price at which no circuits would be routed on the satellite connection of ≥ $6100 the range of price variation was chosen to be $0 to $6100. The upper limit of $6100 was estimated by computing the total of link costs on 2 or 3 of the heaviest TCTS routes through the terrestrial network from Vancouver to Toronto. The intermediate price levels chosen for simulation were

$5000, $3000, $1500, $700, $350

A special group of network cross sections were chosen for analysis to ascertain the effects of rerouting of traffic at various locations in the network. In Figure 2.3 the reader will find a schematic diagram showing the nature of the cross-sections chosen.

These cross-sections or groups of routes are defined as follows

B.C. Access/Exit Route

Two transmission routes leaving the B.C. interior towards Alberta including NPPS routes '196-190' and '196-195'. All terrestrial traffic between British Columbia and Alberta passes by one or the other of these links in the NPPS network representation.

Cross Alberta Route

Three transmission routes crossing Alberta through which pass all terrestrial transit traffic from British Columbia to Saskatchewan and eastwards.

Alberta Saskatchewan Boundary

Two routes carrying all TCTS terrestrial traffic between these two provinces

Toronto Access Routes

Two TCTS routes carrying all interregional traffic between Toronto and Eastern Canada and Toronto and Western Canada, but excluding Toronto/Hamilton/London regional traffic as well as Toronto U.S. traffic.

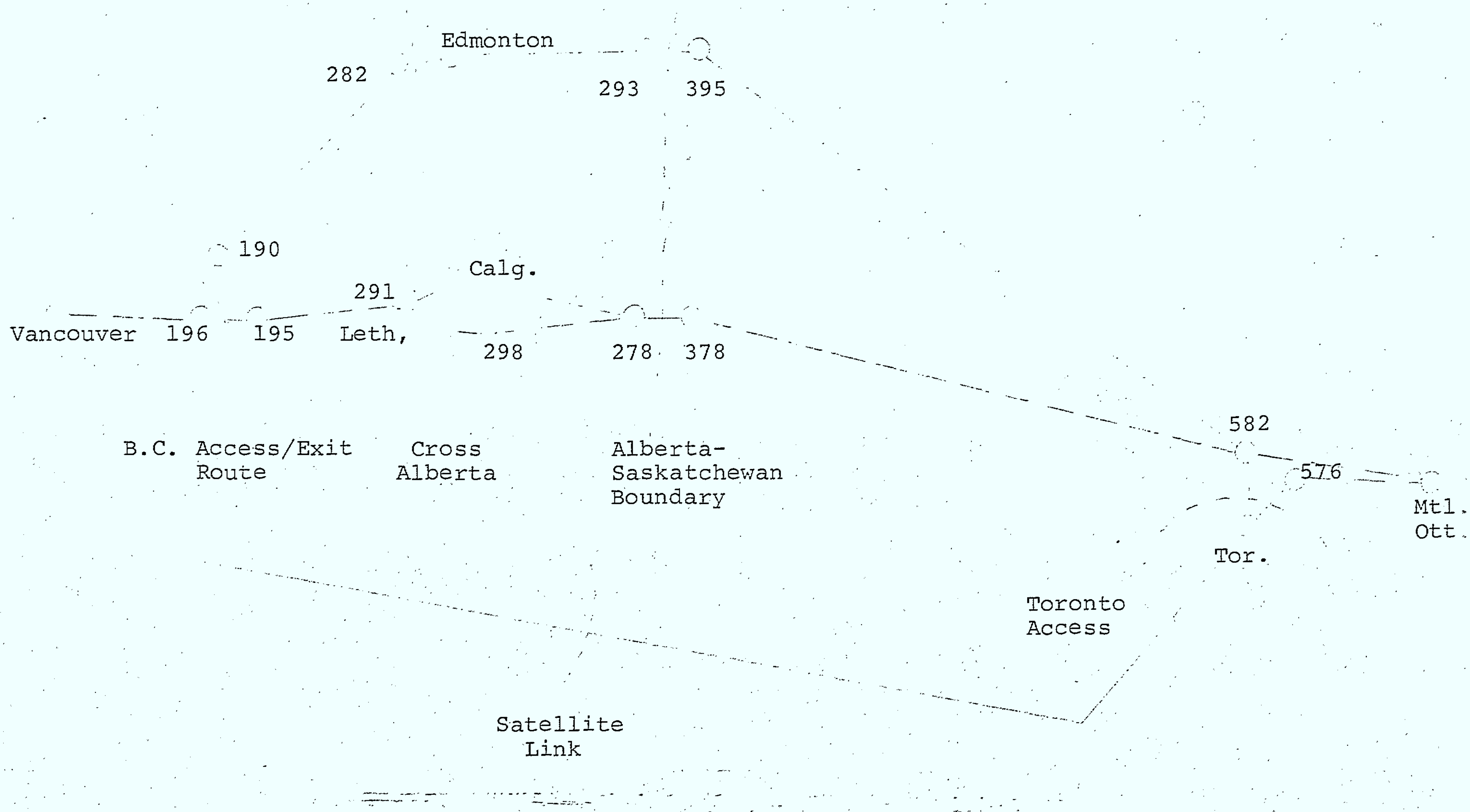
The results of these simulations are discussed below:

i) Composition of traffic on satellite link

In table 2.2 below, the reader will find a decomposition of the switched connections routed via the satellite link as the price declines from $6500 to $0. We may note that, as the price for routing via the satellite declines certain switched connections are rerouted, and that once rerouted, these links remain so routed when the price is further reduced (for obvious reasons). However, without many more points on the price axis it is not possible to say at precisely which price the rerouting via satellite becomes of interest for each individual link.

FIGURE 2.3

NETWORK CROSS SECTIONS USED IN SCENARIO ANALYSIS
SCENARIO 1



2.2 SCENARIO ANALYSIS.

Two scenarios have been considered for the analysis of changes in routing patterns and for the estimation of the equilibrium price level. These scenarios are

I. TCTS leases two earth stations and one channel for message toll and private line service between Vancouver and Toronto. A total of 1200 two way circuits would be available for inter-regional traffic.

II. TCTS leases eight earth stations from Telesat for message toll and private line services. The eight stations are located at Vancouver, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montreal and Halifax.
The total capacity leased is assumed to be one channel with a capacity of 1200 two way circuits.

Finally, the reader is reminded that the "demands" for service on satellite link are not defined in this context as quantities of offered traffic in voice messages but rather as circuit groups which require a fixed routing through the physical network. Hence no change has been made to the switching network database and the simulations made herein concern only the transmission network modules of NPPS.

TABLE 2.2 BREAKDOWN OF SWITCHED CONNECTIONS ROUTED VIA SATELLITE AS PRICE CHANGES

CIRCUIT GROUPS			NO. OF CIRCUITS ROUTED VIA SATELLITE (AT PRICE IN $)	PRICE RANGE WITHIN ROUTING PREFERENCE CHANGES (SPACE SEGMENT ONLY)
NAME	TYPE	#CIR.		
VANC-LOND	H.U.	12		$5000 - $6500
VANC-TORO	H.U.	84	96 ($5000)	"
MONT-VANC	H.U.	48		3000 - 5000
VANC-USS7	H.U.	24		"
VANC-OTTA	H.U.	24	192($3000)	"
CALG-LOND	H.U.	12		1500 - 3000
CALG-TORO	H.U.	84		"
VANC-WINN	H.U.	36	324 ($1500)	"
CALG-OTTA	H.U.	12		700 - 1500
MONT-CALG	H.U.	48		"
TORO-EDMO	H.U.	36		"
VANC-USS3	H.U.	24	444 ($700)	"
EDMO-OTTA	H.U.	12		350 - 700
MONT-EDMO	H.U.	36	492 ($350)	"
CALG-USS7	H.U.	24		$ 0 - 350
VANC-SASK	H.U.	24	540 ($0)	"

* Circuit groups listed for each price range are additional groups added as the price of satellite circuits drops.

TABLE 2.3 CIRCUITS ROUTED ON TERRESTRIAL NETWORK.

PRICE OF CIRCUITS VIA SATELLITE	B.C. ACCESS/EXIT			CROSS ALBERTA				ALBERTA-SASKATCHE-			TORONTO ACCESS		
	196-195	196-190	TOTAL	298-Leth	291-Calg	282-Edm	TOTAL	293-395	278-378	TOTAL	582-Toro	576-Toro	TOTAL
$0.	936	432	1368	252	540	120	792	672	192	792	2448	3972	6420
$350.	936	432	1368	252	540	120	792	696	216	816	2400	3972	6372
$700.	888	432	1320	252	492	120	744	696	264	816	2400	3924	6324
$1500.	816	432	1248	276	396	120	672	804	324	924	2412	3864	6276
$3000.	756	432	1188	312	300	120	612	936	324	1056	2472	3864	6336
$5000.	852	432	1248	408	300	120	708	1032	324	1152	2448	3792	6240
$6500.	948	432	1380	504	300	120	804	1128	324	1248	2544	3792	6336

The ranges shown indicate that, at some price within the range, the cost for routing the individual switched connection by terrestrial links or by satellite are just equal. At the lower value of the price range the satellite route is preferred. At the upper limit of the range, the terrestrial route is preferred.

We may note from table 2.2 that

- the satellite connection will not be saturated at any price however low. A maximum of 540 circuits are rerouted when the price of the connection is zero. This result is explained by the fact that once the basic population areas are served by the satellite the terrestrial cost for backhaul to the satellite earth station limit the zone of "influence" of the satellite. This indicates a requirement for more earth stations near populated areas if the satellite connection is to be used to capacity. (Use of capacity is of course important in order to keep average costs per circuit to a minimum).

- the zones of limiting influence on routing patterns (at a price of zero for routing) seem to be east of the Saskatchewan-Alberta boundary for the Toronto earth station and west of this boundary for the Vancouver station.

- we note that a price in the range of $1500 to $3000 per circuit will encourage backhaul of some Alberta traffic to the Vancouver earth station. Above $3000 no Alberta traffic would be rerouted. In this same price range (1500-3000), the new routing plan would call for backhaul of Winnipeg- Vancouver circuits through the Toronto earth station.

Below $1500 Edmonton-Toronto circuits are back-hauled through Vancouver.

- working from published information on Telesat costs we can obtain an average lease price for circuits on a satellite connection for this scenarios as follows. The lease price of a single channel from Telesat is estimated to be $2,000,000* per annum. The capacity of this channel is 1200 two-way voice circuits. Estimates of lease price for the earth station having a send/receive facility for telephones are $500,000* per annum. The total costs for earth and space segments (excluding backhaul) would be $3,000,000 per channel or $2,500 per circuit. At this price, the NPPS model estimates that 192 to 324 circuits would be used on satellite facilities. At this low level of usage lease prices would be too low to cover total annual costs, since the lease price is based on full use of the available capacity.

ii) Effects on Access Traffic

Figure 2.4 provides the reader with a graphic representation of the affects of introducing satellite service at various annual price levels, on the routing and congestion of the terrestrial network.

This graph is based on the fundamental information obtained from the simulation runs and shown in condensed form in Table 2.3.

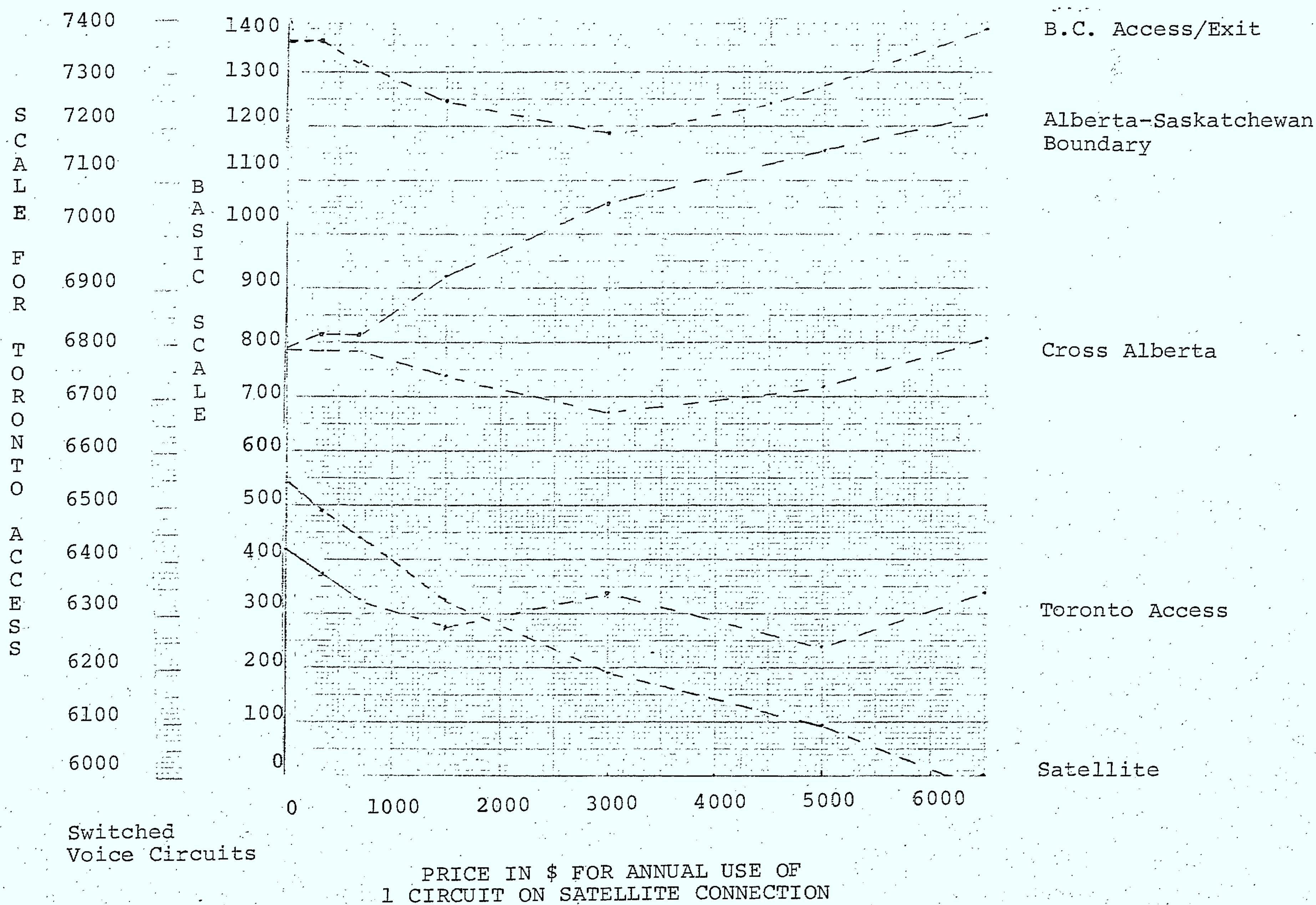
From the results shown in Figure 2.4 we may make the following observations:

----

* Estimates obtained from DOC specialists.

FIGURE 2.4

TRAFFIC VOLUMES IN SEGMENTS OF TCTS NETWORK AS A FUNCTION OF PRICE OF TORONTO - VANCOUVER SATELLITE CONNECTION



- as satellite service is introduced and the price declines, an initial decline will be observed in interregional traffic routed through the B.C. access network. This reflects the rerouting of B.C. originated switched circuits via the space network. At a price near $3000 this effect on the terrestrial network will be most pronounced. As prices fall below these levels however, the rerouting of Alberta originated switched circuits to the east via the satellite will contribute to increase the use of the B.C. access network. In this scenario, an increase back to the original levels of use of the B.C. access network is observed for a price of $0. for satellite routing.

- roughly similar effects are seen on the Cross-Alberta cross-section. We can suppose that the minimum use of these links will occur at a lower price than for the B.C. access/exit network (since these links are further away from the earth station). This hypothesis cannot however be verified with the limited number of simulations performed.

- the situation changes at the Alberta-Saskatchewan boundary cross-section. The effect of rerouting via satellite on this cross-section is a continual reduction of traffic as the satellite price declines to $0.00.

- the Toronto access cross-section is affected in a way similar to the B.C. access network, except that a minor peak in usage occurs around the satellite price of $3000. This is simply due to the network structure and the fact that the Toronto access cross-section is not a complete cross-section of the network. When the price of satellite service declines Toronto-Westbound traffic moves off these links but is replaced by Montreal-Westbound traffic at the same time.

2.2.2 RESULTS FOR SCENARIO II

In the preceeding section it was recognized that the profitability of the satellite connection depends on the strategic placement of earth stations. In this scenario, it has been assumed that earth stations are installed in 8 canadian cities (Vancouver, Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montreal and Halifax). In addition it has been assumed that these stations are directly installed in city centres (hence removing backhaul costs from the city centre to the earth station which were included in the analysis of scenario 1). Under these circumstances several simulations were performed to attempt to identify the per-channel lease price which would just fill the leased channels. The main results are presented in the following tables.

From Table 2.4 we note that a lease price near $2700. per circuit would lead to rerouting of 1152 circuits via the satellite. Of these 40% are due to the Vancouver-Regina and the Regina-Montreal links alone. This result shows that the location of earth stations in cities with high outgoing trunk requirements will be preferable. We also note that the high trunking requirements are related to the levels of hierarchy in the switching network since Regina and Montreal are the final homing centres for western and eastern Canada respectively (and hence have large trunking requirements). The advent of satellite service in the populated areas in southern Canada will possibly have an effect on the organization of the voice switching network depending on the location of satellite earth stations. For example, if initial satellite service uses Toronto, Halifax and Vancouver earth stations it may be of medium term interest to the telecommunications carriers to redesign the switching network in order to use these three cities as final homing centres. Inversely,

TABLE 2.4 - SATELLITE SCENARIO II: USE OF SATELLITE CIRCUITS

	SIMULATED LEASE PRICE PER CIRCUIT					
LINKS	$50.	$700.	$1500.	$2700.	$3000.	$4583.3
TORO-VANC	96	96	96	96	96	96
TORO-EDMO	132	132	132	132	36	0
TORO-REGI	276	276	228	0	0	0
TORO-WINN	168	168	0	0	0	0
TORO-MONT	3024	1104	0	0	0	0
TORO-OTTA	756	456	0	0	0	0
TORO-HALI	216	216	180	84	84	0
VANC-EDMO	252	228	60	0	0	0
VANC-REGI	288	288	288	264	264	0
VANC-WINN	60	60	60	60	60	0
VANC-OTTA	24	24	24	24	24	24
VANC-MONT	48	48	48	48	48	48
VANC-HALI	0	0	0	0	0	0
EDMO-REGI	456	324	60	0	0	0
EDMO-WINN	132	132	120	0	0	0
EDMO-OTTA	24	24	24	24	24	0
EDMO-MONT	84	84	84	84	84	0
EDMO-HALI	0	0	0	0	0	0
REGI-WINN	360	180	0	0	0	0
REGI-OTTA	48	48	48	0	0	0
REGI-MONT	276	300	348	204	204	0
REGI-HALI	24	24	24	24	24	12
WINN-OTTA	12	12	12	0	0	0
WINN-MONT	420	396	96	0	0	0
WINN-HALI	12	12	12	12	12	0
OTTA-MONT	1656	0	0	0	0	0
OTTA-HALI	48	48	48	24	24	0
MONT-HALI	588	432	252	72	72	0
TOTAL	9480	5112	2244	1152	1056	180

TABLE 2.5 SATELLITE SCENARIO II: LEASE REVENUES.

	$/CIRCUIT	# CIRCUITS ALLOCATED	LEASE RE-VENUES(1) ($000,000)	CHANNELS REQUIRED (2)	LEASE COSTS(3) ($000,000)
CASE 1	$ 50.	9480	$0.474	8	$20.000
CASE 2	700.	5712	3.578	5	14.000
CASE 3	1500.	2244	3.366	2	8.000
CASE 4	2700.	1152	3.110	1	6.000
CASE 5	3000.	1056	3.168	1	6.000
CASE 6	4583	180	0.825	1	6.000

(1) Lease revenues are obtained by multiplying the per circuit price by the total number of allocated circuits.

(2) The number of required channels is obtained by division assuming 1200 circuits per channel.

(3) Lease costs are based on 8 earth stations at $500,000. annual lease each and $2,000,000. per leased channel.

in order to use satellite facilities efficiently to support voice transmission it may be most cost effective to locate earth stations near each of the higher level final homing centres in each region since circuit requirements are heavier in these areas.

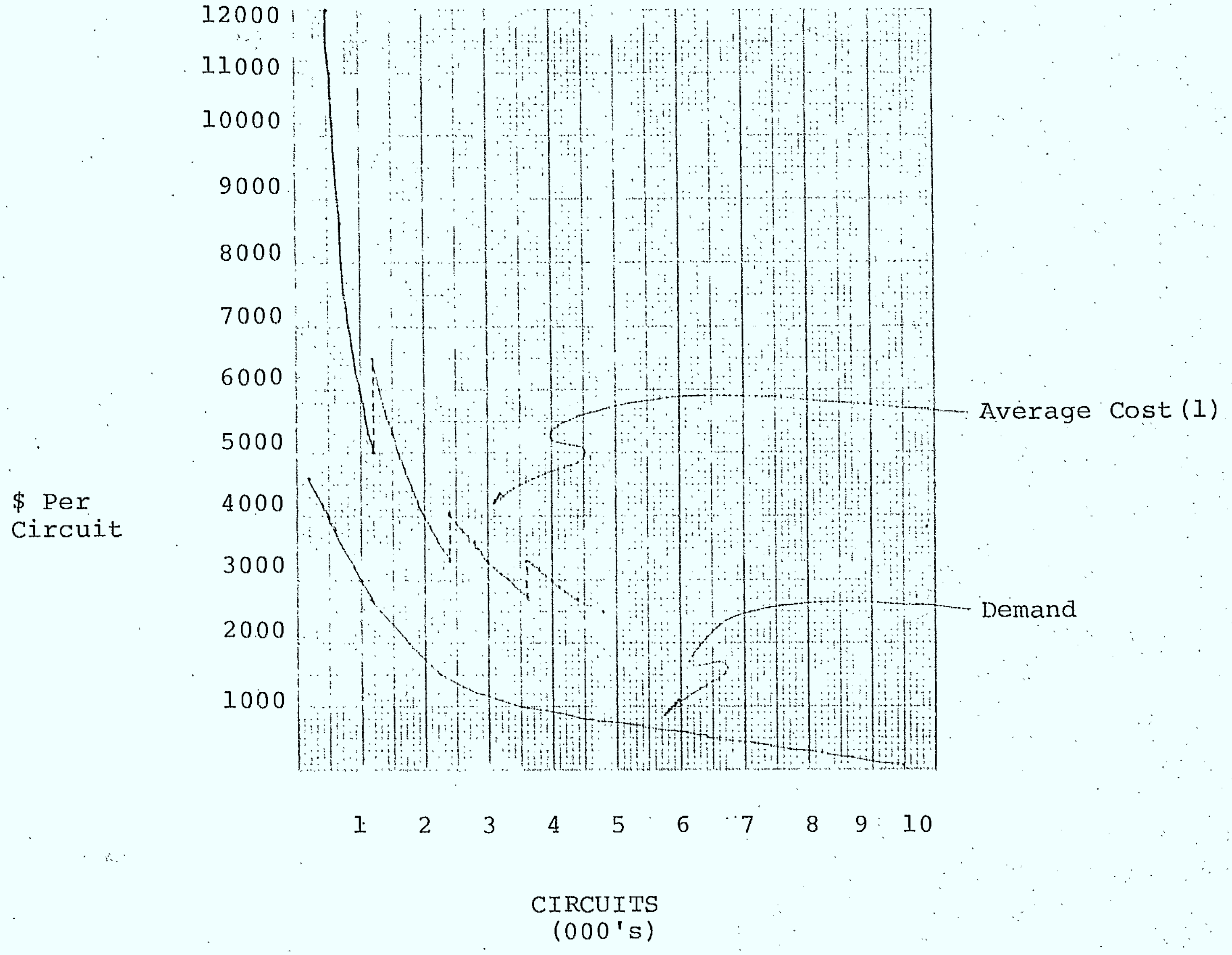
Finally we note that, even in this configuration, demand for satellite circuits will not be sufficiently high at any simulated price for revenues to exceed lease costs. This can be seen in Table 2.5 where total lease costs are calculated on the basis of the number of channels required (plus the lease of 8 earth stations) and where total revenue is computed as the product of circuits used and simulated price.

A second demonstration of this point is seen in figure 2.5 where the demand curve is shown with the average lease cost curve for satellite circuits. The average cost exceeds the equilibrium price for every possible level of demand. If average costs were cut in half, the equilibrium usage level would be roughly 1000 circuits (intersection of demand and average cost curves).

FIGURE 2.5

SATELLITE SCENARIO II

DEMAND AND AVERAGE COST



(1) Based on 8 Earth Stations and Up To 4 Channels

3.0 INTERCONNECTION OF CNCP AND TCTS

3.1 INTRODUCTION

In the following section we reviewed methods of investigating some issues raised by the interconnection of CNCP and TCTS networks, using NPPS.

No numerical work has been performed on this topic mainly because of the following points:

- a fairly large effort is required to add CNCP facilities to the NPPS database;
- the larger network created by the addition of CNCP to the NPPS database would exceed the size limitations of NPPS software (transmission routing algorithm specifically);
- cost functions allowing for the estimation of replacement values of CNCP equipment and of annual costs are not included in NPPS.

The major software obstacle (network size) has been studied in this contract (see Operational Evaluation of NPPS Section 5.4) and certain methods of overcoming this obstacle have been discovered.

The present section will however be limited to a discussion of how to use NPPS for the analysis of the CNCP/TCTS interconnection question and of the types of results which could be obtained.

3.2 METHODS OF EXAMINING EFFECTS OF INTERCONNECTION

In the context of linear programming the issues related to interconnection may be addressed as follows:

We formulate the basic linear programming problem as in the current version of NPPS wherein

- the additional links and nodes required to represent the CNCP network are added to the NPPS network;
- special "inter-connections" are made available between the TCTS network and the CNCP network.

These "inter-connections" would be set up as follows:

- each of the facilities (links) in the network would be labelled in a way which identifies the type of circuits which can be routed via this equipment. TCTS transmission links would be labelled to accept telephone and private line traffic. CNCP transmission facilities would be labelled to accept private line and message record traffic only;
- additional access links would be introduced into the network to represent the points of interconnection between the two networks. These access links could be few or several in number depending on the scenario and would be used as "control gates" for traffic routed from TCTS subscribers through CNCP facilities.

- if CNCP demand data is available (mostly private lines of various sorts) these demands can be included with the other network demands and allocated simultaneously on the integrated network. In the case of CNCP private line demands, the TCTS facilities would be labelled as unaccessible to this traffic in the routing algorithm.

Having set the problem up in this fashion we note that several new constraints have been added and that the problem will therefore be considerably larger. These constraints are:

- one new capacity constraint for each CNCP transmission link added;

- one new capacity constraint for each "interconnection" between CNCP and TCTS networks;

- one new demand constraint for each additional CNCP private line demand if these are routed simultaneously.

A labelling method may be extended to several different types of commodities if required. In general if there are different commodities (i.e. classes of traffic such as Telephone, CNCP digital, CNCP analog, TCTS private line, etc..) the labelling scheme would consist of the assignment of a binary vector to each transmission link as follows

$$B_i = (b_i^1, b_i^2, \ldots, b_i^n)$$

where $b_{,}^{i}$ takes values of 0 or 1 and

where $bi^j = 0$ means that commodity j may not be assigned to link i, and

where $bi^j = 1$ means that commodity j may travel by link i.

Simultaneously each demand pair (or demand constraint) would be labelled with a binary vector

$Dj = (0,0,\ldots 1,0,0,\ldots)$

where n-1 entries have value zero and exactly one entry has the value of 1. The position of the entry having value 1 determines the type of commodity to which the demand constraint j belongs. (if 1 is in position 2 then this demand constraint is for commodity 2).

With this labelling arrangement it will be possible to limit the use of facilities to those types of demand which are labelled appropriately.

In particular:

$Bi \times Dj = 0$ means that demand pair (or constraint) j may not be routed via link i.

$Bi \times Dj = 1$ means that demand pair j may be routed via link i.

This labelling system may be applied to the current NPPS route assignment algorithm or to the replacement alogorithms provided in the report on the operational evaluation of NPPS (Operational Evaluation of NPPS Section 5.4).

The storage requirements for the binary vectors required for this type of algorithm are calculated by the following formula:

$$\frac{1}{32} \times \text{number of commodities} \times (\text{number of links} + \text{number of demands})$$

For the current version of NPPS, assuming 3 commodities and inclusion of the CNCP network, this represents a requirement for

$$\frac{1}{32} \times 3 \times (432 + 300^{*} + 281 + 200^{*}) = 114 \text{ words of storage}$$

(* estimated 300 CNCP transmission links and 200 demand pairs for CNCP private line service).

Thus this labelling procedure will in no way hinder the development of an algorithm to handle larger networks. (Even with 32 commodities only about 1200 words of main storage are required).

Within the above formulation at least two types of analysis may be performed. These are

1) Investigation of the amount of business lost by TCTS as a function of the price of access to the TCTS network. This analysis would be accomplished by allowing unlimited access capacity at the chosen interconnection points and varying the price per circuit for access through a range of values. For each access price level an optimal (or near optimal) routing scheme would be found using NPPS. Analysis of the route assignment corresponding to each access price would permit the determination of the amount of business lost by TCTS in the private line sector. Since the optimal routing is obtained in a cost minimization formulation, the interpretation would be based on the hypothesis that rates reflect costs to carriers and that the minimum cost solution is similar to the minimum price solution chosen by consumers. If this hypothesis is accepted the loss of business to TCTS can be measured as the number of TCTS demand pairs routed by the CNCP network. Furthermore, if it is assumed that TCTS is allowed to charge an access fee to CNCP for each circuit carried on the access links, it will be possible to determine the level of revenues generated by such an access fee.

2) Estimate of the relative value to consumers of access to CNCP at different capacity levels. In this analysis a null access cost would be assigned to interconnection links and capacity would be varied from low to high values. The results of the optimal routing and, in particular, the shadow prices at each level of capacity on the access links, would provide a measure of the value in terms of overall cost reduction of extra units of access capacity.

In both cases, since annual costs are essentially independent of usage in the short term, it will be of interest to calculate total revenues for TCTS and CNCP and to relate these to levels of revenue attained without (or before) interconnection. This approach would allow for the calculation of revenue (or profit) losses or gains by each carrier on a pure accounting basis.

In economic terms, however, losses to TCTS must be measured as follows

- if interconnection introduces a need for TCTS to install new equipment only then the loss to TCTS is only the replacement value of the equipment;

- if interconnection at some access price causes a loss of existing TCTS customers to CNCP (as distinct from an increase in the total business of the two carriers) then the loss to TCTS is the profit previously made in provision of service to such customers.

As discussed above, NPPS will allow us to measure the second loss, but not the first.

3.3 MODIFICATIONS TO NPPS DATABASE AND SOFTWARE

In order to carry out such a study changes and additions to NPPS would include the following:

i) inclusion of the CNCP network in the NPPS database. This activity would require the use of the ROUTE database for the indentification of CN/CP facilities and the preparation of the data in the NPPS facilities and the preparation of the data in the NPPS formats. (This includes identification of corrections, nodes, channels and capacities). The ROUTE database contains much more data than required by NPPS and is, for this reason difficult to access. Identification of modes and links requires some detailed analysis of tower locations and transmission frequencies. In addition the database is known to contain a certain number of errors and inconsistencies which many hinder the development of a coherent database for NPPS.

ii) Development of methods of estimating annual costs, and asset replacement values for CNCP equipment. Since CNCP transmission facilities use the 6 giga hertz band, it cannot be assumed that costing and valuation functions are identified to those used for the TCTS equipment (transmission in the 4 giga hertz band). If analytical cost functions are available these may be incorporated directly into the NPPS program modules.

iii) replacement of the route assignment algorithm (NPPS) by one which will handle a larger network. Inclusion of CNCP facilities and demands can be expected to nearly double the number of constraints in the LP problem. This problem is too great for the current algorithm used in CIRRES.

iv) identify or estimate the existing demand for private line circuits on the CNCP network. This identification process may also involve the separation of total traffic into various service classes. The identification of commodities will be required if it is decided that TCTS will have access to current CNCP customers in particular service classes. If competitive services are to be separately identified any extent for the purposes of routing. Such identification will be required for both TCTS and CNCP demand pairs.

Of these four modifications to NPPS, i), ii) and iv) involve data gathering and data manipulation. Modification iii) involves the replacement of one of the fundamental algorithms in NPPS. In view of the relatively large amount of work involved these tasks have not been undertaken in this contract, (except for the identification of a new algorithm to replace CIRRES).

4. ADAPTATION OF NPPS FOR ANALYSIS

4.1 CONVERSION OF NPPS TO BATCH MODE OPERATION

Since several of the conversational programs used in NPPS are long in execution time and, in conversational mode, require continuous occupation of the terminal device, it was decided to convert sections of the system to batch mode.

The conversion principle used involves the creation of conversational response files for each of the programs. These conversational response files contain, in sequence the responses to questions posed by each NPPS module in its conversation. The files contain in sequential order the responses required by the program during execution. When these files are created in advance and stored in the appropriate permanent disk devices, the "conversational" program can be executed in batch mode and directed to obtain its responses from the conversation file.

This conversion required the following activities:

1. Review of NPPS conversations to create appropriately structured conversation files.

2. Passage of each program in batch mode with large core and time limits in order to measure core occupancy and time duration. These data are required in order to submit batch jobs for effective use of resources and are not available through conversational outputs.

3. Analysis of the model structure to create a sequential processing plan for various modules. (This sequential processing plan is provided in Figure 4.1. The batch modules include the core of the operating, costing, and sharing blocks but exclude the peripheral programs since these latter programs require low run time and involve no large files.

4. Creation of special batch submission files.

5. The routing of program output normally destined to the terminal device to a disk storage device for later recovery.

In this mode of operation, the NPPS user will, typically:

1. adjust the parameters and responses to reflect the analysis desired in the conversation response file;

2. submit the batch job for overnight processing;

3. recover the desired results from the disk files after the processing is complete.

The advantages, of course, are two fold.

1. the user does not have to remain seated at the terminal while programs are running. The termi-

nal can be turned off after the jobs are submitted. The preparation of conversations are relatively much more rapid.

2. The CRC systems operation acquires the flexibility of scheduling large batch job in off peak hours and may optimize the use of their facilities.

In the following paragraphs, we provide an outline of the method of operation of NPPS in batch mode.

1. The conversational response files names are formed by adding the prefix I to the file name. Hence ITRAFES is the conversational response file for the module TRAFES and so forth. These files may be recovered and updated using the CPV editor.

2. The program results file name is formed by adding the prefix G to the program name. Hence GTRAFES is the output file containing the output of TRAFES after a simulation.

3. The submission of a batch job is performed (for individual NPPS modules) by typing the command.

   BATCH J'name'

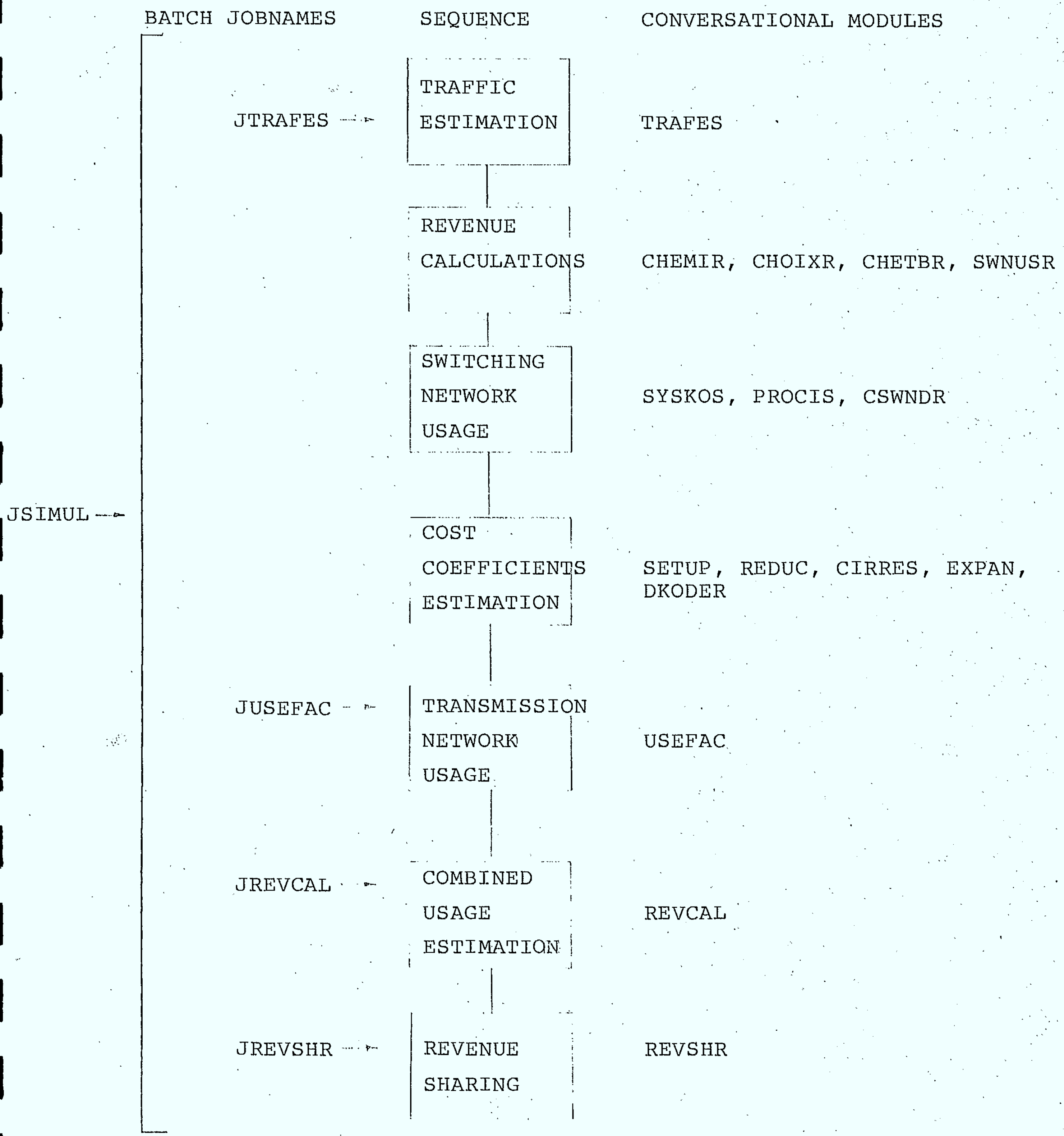
   where the batch module name is formed by the addition of the prefix J to the conversational module name.

4. Several batch jobs may be submitted in cascade by typing the command.

BATCH JSIMUL

This is a batch job which submits a series of other batch jobs in the appropriate sequence and thereby allows the uses to set up a cascade of batch jobs in one command. The typing of this command amounts to the submission of the entire core of the simulator as defined in Figure 4.1.

FIGURE 4.1- CASCADE SEQUENCE FOR BATCH JOBS.



4.2 NEW PROGRAMS DEVELOPED FOR ANALYSIS OF COST SEPARATION

For the application of the cost allocation principles described in section 1, several new programs were developed and added to the NPPS model. These are described very briefly below.

1) SBCPR3: Program to extract usage information from the combined usage estimate files and break this usage down into the 4 categories of adjacent, regional, interregional and Canada-USA traffic. The program produces these breakdowns on a device by device basis.

2) SBCPR5: Program to translate the basic usage information obtained above into percentages for subsequent use.

3) SDCPR6: Program to apply element usage percentages to the costs and assets of NPPS equipment and to sum these percentages on a company by company basis.

   The results of this program provide the average cost allocation discussed in section E of this report.

4) SDCPR7: Program to apply the cut-off assignment method to individual equipment and assign elements to an interregional operating body.

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