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LAND MOBILE INVENTORY STUDY
FINAL REPORT

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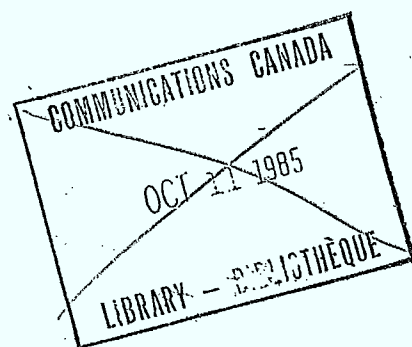
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FINAL REPORT

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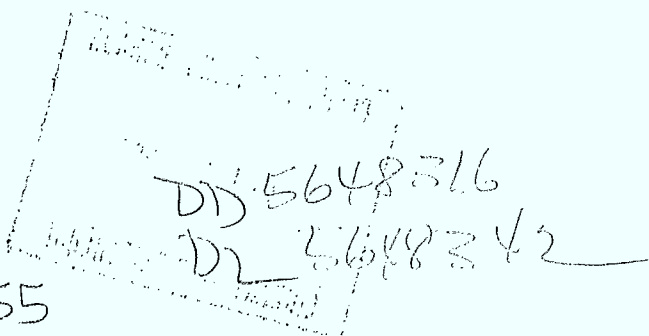


August, 1979

Prepared By:



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This Study was carried out on contract to the Department of Communications. The views expressed in this report are those of the Consultant and do not necessarily represent the views of the Department.

Note: Two major revisions were needed to the document presented by the consultant, in order to publish.

Firstly, the "costing analysis" section of their report has been removed to ensure proper confidentiality of the manufacturers' costing data.

Secondly, the financial analysis statistics were recalculated by DOC, using the methodology developed by Cantel, to include additional manufacturing statistics available only to DOC.

The consultant has been notified and agrees with the above changes.

EXECUTIVE SUMMARY

1. This report developed dollar values for Canada's Mobile Radio Inventory associated with five DOC District Offices in three frequency bands: 150 - 174 MHz, 410 - 420 MHz, and 450 - 470 MHz.
2. It has proven feasible to use departmental files to establish Inventory age distributions for Land Mobile Radio Systems. Information from Land Mobile Suppliers and limited number of municipal users has also been used to establish dollar values.
3. It is concluded that the data base structure developed for the three frequency bands in this study can be readily adapted to similar valuation techniques for other frequency bands and geographic areas.
4. The following financial summary (based on Tables 5 & 6) totalizes various values for all three frequency bands associated with all five District Offices:

Net Present Value (NPV)	- \$124,778,421.00
Net Present Value in 1978 dollars (NPVF)	- \$182,379,733.00
Salvage Value	- \$ 3,336,027.00
Replacement Cost	- \$138,051,216.00

Note: NPV is based on the actual price in the year of sale and does not incorporate the effects of currency inflation. NPVF is based on the price in the year of sale that has been adjusted in accordance with the consumer price index relative to the year 1978.



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Appendix I	Work Statement
Appendix II	Company Code Data
Appendix III	Age Distribution Data
Appendix IV	Letter to Manufacturers

Note: Appendix II and III not included in general distribution.



1.0 INTRODUCTION

Cantel Engineering Associates Ltd. was retained by the federal Department of Communications to conduct a Land Mobile Inventory Study. The objectives of this study have been:

- (1) "To test a method of assessing the economic impact of spectrum policy changes on a Land Mobile Radio Equipment Inventory in Canada, and to test this method for one or more given problems with particular emphasis on quality of results and accessibility and quality of the needed data."
- (2) "To create a data base to be used in such impact assessment (assuming the achievement of objective #1) which will allow estimates to be made of inventory value in various frequency bands and geographic areas and which will include information on equipment age and cost structures."



2.0 DISCUSSION

This study has been undertaken with the intent of establishing a value on today's mobile radio inventory in Canada. As a practical constraint the study has been confined to a limited number of frequency bands in pre-determined urban sectors across the country.

There are several ways in which the Land Mobile Inventory in Canada could be estimated. Perhaps the most thorough would be an actual user survey where all licencees in the country would be canvassed with a questionnaire to determine their historical inventories. This technique would be extremely costly to DOC and would impose a significant load on the private sector.

A second method would be to canvass all suppliers with the intention of arriving at detailed and historical sales statistics. This technique is not feasible due to the lack of geographical sales distribution information and the extremely competitive nature of Land Mobile manufacturers. It has been found that the major Land Mobile suppliers do not keep accurate records of the destination points of their shipments. For example, large quantities of Land Mobile equipment shipped to the R.C.M.P. might show an Ottawa address whereas the equipment is being distributed throughout the country.

A third technique, and the one which has been employed in this study, is a statistical analysis of the DOC licence files combined with a limited canvassing of suppliers, some comments from users and informed comments from District and Regional DOC staff.

This study looks at the net present value (with and without inflationary effects), replacement cost and salvage value under three separate conditions:



(a) Class of Equipment

Three classes of equipment have been considered.

- (i) Land Stations, which are defined as radios with transmit and receive capability at a fixed location, eg. a Base Station which normally transmits to and receives from Mobiles; and Repeaters, which normally relay traffic from one Base Station or Mobile to another Base Station or Mobile. Costs later developed for this class include the transceiver, typical antenna, transmission line and filters.
- (ii) Mobile, a radio with transmit and receive capability which is normally mounted in a vehicle and is thus "mobile" in nature. The costing section covers the Mobile and its antenna system.
- (iii) Portable, a radio with transmit and receive capability which is normally hand-carried and has a self-contained power supply.

In this report, the above three classes of equipment will be referred to collectively as "Land Mobile" stations or equipment.

Paging devices with receive capability only have not been considered in this study. The limited number of pagers with transmit capability have, however, been included. These are classified under item (iii) above, Portables.

(b) Frequency Band

Land Mobile equipment operates in a number of frequency bands. This study is confined to only three bands, however:

150 - 174 MHz

410 - 420 MHz

450 - 470 MHz



(c) District Office

This study analyzes the value of Land Mobile stations licenced through the following DOC District Offices only: Vancouver, Edmonton, Calgary, Toronto and Montreal.

At the outset of the study, a visit was made to all District Offices where a broad cross-section of Company Code files was pulled and examined in detail (see Section 3.2).

The company code file represents the documentation set up between Land Mobile applicants and the Department. It includes such material as licence applications, copies of licences when issued, inspection reports and all correspondence related to the licensee.

The validity of the Company Code file inventory statistics with respect to inventory shown in the Integrated Radio Station Licencing System (IRLS, see Section 3.1) was established as well as the validity of Company Code file inventories versus actual inventories for a number of municipal and other licensees (see Section 3.3). Following these validity checks, it was decided that IRLS statistics would be used to produce inventory age distributions for the various frequency bands in the five district offices. Statistical techniques which are described in detail in Section 4.0 were then used to determine depreciated as well as undepreciated growth constants for various industry categories to enable a statistical evaluation of age distribution constants used to define mobile equipment inventory.

The other aspect of the work has involved development of average sales price information for land, mobile and portable stations over the past several years. This information could be and was in fact used in the statistical formulas developed in Section 4.0 to arrive at net present values of the inventories.



In order to understand how the Land Mobile inventory values have been arrived at, it is necessary to thoroughly understand all sources of information and the application of these sources in the statistical and financial analysis. The information sources are discussed in detail in Section 3.0, starting with a description of the IRLS and its validity as a basis for the age distribution, followed by an account of the information gleaned from Company Code files. A description is given of information received from one major class of users - municipal governments - and the actual number of units and licenced no. of units have been compared (see Table 2). Finally a summary is given of the essential price information received from manufacturers.

It is essential that Section 4.0, the Sampling Methodology, be well understood in order to follow the details of the financial analysis and subsequent sections. Notwithstanding this comment, and bearing in mind that some readers may not wish to have full knowledge of the detailed analysis, Section 5.0 has been organized to use the various equations of Section 4.0 to arrive at: net present value, net present value in 1978 dollars, salvage value and replacement cost for the various classes of equipment licenced in the five district offices in the 150 - 174, 410 - 420 and 450 - 470 MHz bands.



3.0 INFORMATION SOURCES

3.1 Integrated Radio Station Licencing System (IRLS)

Information associated with radio licences in Canada (with the exception of the General Radio Service) is held and constantly up-dated in the DOC's computerized IRLS. The IRLS was designed to "manage the financial aspects of the licencing process, and thus only licences in force during the current fiscal year appear on the system".

Within the IRLS, year-end files have been created, where each year-end file is a snapshot of the IRLS at that particular point in time. These files go back to the year 1972 and, for each record on the file, it may be determined whether a licence was active, cancelled or relocated during a given year.

One problem, as far as the aims of this study are concerned, is what has become known as the "cancellation problem". Due to the manner in which the IRLS has been organized, it is impossible to determine the number of licences issued in a specific year prior to 1972. The information shown in any year-end report for years prior to 1972 represents licences which have survived until 1972 or later. The connotations of this problem are further discussed in Section 4.4 and, due to depreciation considerations, it is not as serious as one may initially suspect. A number of other problems associated with the IRLS are also discussed in Section 4.0.

The computerized structure of the IRLS makes it highly flexible to varied forms of output. One type of output that has been extremely useful to this study is "The Number of Land Mobiles by Band and Year, Summarized by Sector and District Office" referred to as Table 01 in the computer output. A sample of this table is included as Figure 1.



A set of Table 01's, as of this date, is available for seven consecutive year-ends, from 1972 through 1978. It has been determined that, in terms of actual quantities, only the accuracies of the final year figures can be assured. Earlier years for a given Table 01 are apparently subject to errors as a result of overlap and other problems. Nevertheless, it has been concluded that these figures are suitable for trending purposes to arrive at depreciated aging schedules as discussed in detail in Section 4.0.

The IRLS age distributions as referred to above have been used to determine values of mobile and portable equipment only. Computerized data output for Land Stations, however, has not been organized to correlate with District Office boundaries. As described in Section 3.2, Land Stations represent, on the average, approximately 10% of the current Land Mobile units. Certain assumptions have therefore been made with regard to depreciated and undepreciated quantities, enabling the techniques for mobile and portable analysis to be adapted to land station analysis.

Section 4.0 of this report discusses the ramifications of using Table 01 to determine the age distribution. The major factor which impacts on the accuracy of Table 01 is the replacement of mobile equipment by a licensee under an existing licence with new or second-hand equipment. Replacement with second-hand equipment has been established as being of a minor nature in that suppliers advise that second-hand or reconditioned equipment contributes less than 10% of their total sales. With respect to replacement with new equipment, the depreciation rates calculated from Table 01 plotted data correspond with manufacturer experience in typical write-off periods.

Other sources of error, for example Municipal licencing, will be discussed in Section 3.3 of this report.



3.2 Company Code Files

Since details regarding equipment are not available on the IRLS and since users can change equipment, it was decided to examine the Company Code files.

At the beginning of the study, an attempt was made to define three depreciation categories for various industries. For compatibility, the Standard Industry Codes used by the federal Government were used and the three groupings are shown in Table 1. The criterion used for this assessment was subjective experience rather than manufacturer or licence statistics and the framework was established to enable a sampling of company code files in the five district offices. The samples chosen were roughly in proportion to the quantity of licences in a depreciation category and a total of approximately 45 company code files were pulled and examined in detail in each district office. The company code numbers were extracted at random from the IRLS within each depreciation category; however, specific municipal files were pulled to investigate potential sources of inventory error.

In actual fact, and following a detailed investigation of depreciation rates and manufacturers' data, it was found that it is not possible to generalize depreciation rates for SIC categories in all district offices. Where it was originally anticipated that reduction of company code file information would be essential to establishing age distributions, such has not been the case. The real value of the random assessment of approximately 225 company code files has been:

- (a) To verify the average ratio of Land to total Land Mobile Stations. This ratio has been found to be approximately 10%, with some variation with specific SIC categories. For example, the ratio is obviously much lower for the taxi industry.



- (b) A verification of the IRLS reporting mechanism for Land Mobile quantities associated with municipal licencees. Table 2 summarizes this verification for a few select municipal licencees.
- (c) A verification of the ratio of Portables to total Land Mobile stations. Due to the similarity in price structure between Portables and Land Mobiles, however, these two categories have been grouped together in the financial assessments.
- (d) A thorough investigation of the five district office company code files and their associated data bases, enabling a few specific recommendations for better information on the age distribution of inventory to be made in Section 7.0 of this report.

For each company code file investigated, the following information was recorded:

- i) Name of company
- ii) Number of Land & Mobile licencees
- iii) Manufacturer names & model numbers of all base stations, mobiles and portables listed in licence applications and the application dates.
- iv) Frequency identification for all equipment.
- v) Inspection report verification, if available.
- vi) Name and phone number of contact for municipal licencees.

Details on each file examined are referenced in Appendix II.

A few words should be said of the impact of Restricted Common Carriers and telephone companies to the Inventory Study.



Due to the fact that a large number of companies require Mobile Radio services yet cannot justify a system of their own, the Restricted Common Carrier Mobile Radio Service, or RCCMRS as it is commonly known, has developed. RCCMRS operations typically operate one or two repeaters which are used by their customers. In addition to providing Land Station services to customers, the RCCMRS operator also transmits signals on behalf of paging companies. The paging devices, which may be owned either by the RCCMRS or the paging company, are receivers without transmit capability. Although they must be approved by the Department of Communications, they are exempted from the usual licencing procedures for Land Mobile equipment with transmit capability. As a result, paging devices have been excluded from this Inventory Study.

RCCMRS operators in major urban areas tend to co-locate Repeaters with one another, due to the limited number of sites with the required coverage capabilities and the high cost of site development. Common antennas are frequently used utilizing radio frequency combiners which interface the antenna with a number of Repeaters. The number of such installations with respect to the overall Land Mobile Inventory is extremely low, however, and for this reason RCCMRS equipment is not dealt with separately in this study.

With regard to the General Land Mobile Radio System, commonly known as GLMRS or simply MRS and operated by the telephone companies, all Mobiles are licenced for MRS application to the user rather than to the telephone company. There is a vast number of licences issued to users of the MRS service. All Mobiles licenced for this service operate through telephone company Land Stations with interconnect to telephone subscribers. In addition to MTS land stations, the telephone companies are also licenced for Mobiles and Portables, but for their own internal operation.



In all cases, the quantities appear to be well recorded via licence applications and it would seem that all telephone companies have at least one individual who is responsible for the accounting of mobile equipment and regulatory matters with the DOC.

3.3 Municipal Government

For the five district offices visited, a number of municipal files were pulled to compare IRLS quantities with applications. A further check was made on the validity of this data by contacting specific municipalities.

The licencing procedure for municipalities has been as follows. Normally only two licences will be issued to a specific municipality, a green licence which covers Land Stations, and one yellow licence which covers any number of Portables and Mobiles. In contrast all other licencees have one licence per mobile. The quantity of Mobiles submitted by the licensee in his application is recorded on the yellow licence and this quantity is recorded in the IRLS.

It was found generally that the larger the municipal user, the more accurate is the reporting procedure. This is due to the fact that large governmental users, eg. Metropolitan Toronto Police, have such large inventories that a member of staff is assigned on a full-time basis to keep track of their inventories and advise the Department of all changes affecting quantities and other relevant information for Land Stations, Portables or Mobiles.

Even in the case of smaller municipalities, such as Northumberland County in Ontario and Richmond municipality in B.C., it was found that the equipment inventory corresponded closely with the associated company code files. There are no doubt instances of errors between actual and reported quantity with certain municipalities. On the basis of the municipalities polled, however, it is unlikely that these errors would produce any significant changes in the inventory calculations in Section 5 of this report.



Table 2 is a list of municipalities, listed alphabetically, with IRLS inventories and actual inventories reported to Cantel by the licensee. The average range of errors for all of the company codes listed in this table was: -9.6 to +5.0%.

3.4 Manufacturers

Whereas the IRLS data base has been the primary source of quantity information for analysis, the contractor has depended on the manufacturers for providing historical pricing, and other indexes as shown in Appendix IV.

A copy of the questions to manufacturers requesting specific sales and price information is included as Appendix IV.

Prices received have been compared with dated catalogue prices in Cantel's library and have been cross-checked with a few selected large customers, and are considered representative of the market over the past seven years. The pricing trends have been extrapolated graphically for the following categories: Mobiles / Portables combined and Land Stations. The straight lines approximating the plotted points have provided a price growth constant for each category which has been used in all financial analysis.



4.0 SAMPLING METHODOLOGY4.1 GLOSSARY OF SYMBOLS AND ABBREVIATIONS

$A_j(N)$	=	(depreciated) age distribution for class j
β, α	=	depreciated growth constants
A	=	$dQ/dN = A(N)$ = approximates a snapshot of the (uncorrected) age distribution of the number of mobile units initially licensed in year N and remaining in service in the final year Y.
ϕ	=	price growth constant
C	=	number of equipment classes
d	=	depreciation rate
Δ	=	difference in growth rates ($\Delta = \beta_2 - \beta_1$)
F	=	suffix indicating that the value is for the final year eg. NPVF, UF
γ	=	undepreciated growth constant
i	=	inflation rate (sect. V) or unit (sect. VI)
IRLS	=	DOC Radio License System
j	=	unit class
$M(N)$	=	undepreciated number of units sold in year N
N	=	number of years from a beginning year
NPV	=	Net Present Value
NPVF	=	Net Present Value in 1978 dollars
Q	=	cumulative number of mobile units
$Q(Y)$	=	total number of units in service at the end of year Y
RC	=	Replacement Cost
$R(N)$	=	replacement cost of units manufactured during year N
SIC	=	Standard Industry Classification
$S(N)$	=	scrap value of units manufactured during year N
σ^2	=	variance
SV	=	scrap value
$U_{ij}(N)$	=	sale price in year N of a particular unit i in class j
$U_j(N)$	=	average per-unit cost of class j equipment in year N
$U(N)$	=	per unit cost in year N
Y	=	final year
$\delta A_j, \delta U_j$	=	estimation errors



4.2 INTRODUCTION

Assessment of the impact of hypothetical policy changes involving utilization of the electromagnetic spectrum requires knowledge of the economic value of the mobile equipment inventory. As a starting point the Department of Communications has requested an inventory study for five district offices (Vancouver, Calgary, Edmonton, Toronto, and Montreal) and three frequency bands (150 - 174 MHz, 410 - 420 MHz and 450 - 470 MHz). Also requested is an assessment of the methodology used for inventory determination. The methodology must be developed in accordance with the available data and the level of effort budgeted for gathering and processing this data and for presenting the results obtained therefrom.

4.3 ECONOMIC MEASURES OF INTEREST

The principal economic measures of interest for the land mobile equipment inventory include net present value (NPV), scrap value (SV) and replacement cost (RC).

The NPV of a single inventory unit is the initial cost of the unit less depreciation. The NPV of the inventory is the sum of NPV's of each and every unit. Since it is clearly not feasible to determine exactly the NPV of the inventory, a viable estimation approach must be developed. One approach is to estimate: (a) the average number of units sold each year, (b) the cost per unit or if there are classes of units the per-unit cost in each year for each class, and (c) the depreciation rate. These estimates would then be used to estimate NPV. Classes selected might include vehicle-mounted mobiles, portables and base stations.

The NPV as determined above is based on the actual price in the year of sale, and does not incorporate the effects of price inflation. Adjustment of the sale price in any year in accordance with the consumer price index or some other suitable index yields NPVF, the net present value in terms of final year dollars. In the analysis, the consumer price index, averaged over the past eight years, has been used.



The scrap value of the inventory can be estimated by multiplying the total number of inventory units in each class by the per-unit scrap value, and adding the resulting dollar values.

The inventory replacement cost is estimated by multiplying the total number of inventory units in each class by the per-unit cost of replacing the unit in question, and adding the resulting dollar values. Difficulties would occur in those situations where replacement units available perform functions additional to those of the unit to be replaced.

To determine the economic quantities of interest requires estimation of the age distribution of the land mobile equipment inventory, as well as depreciation factors and sale prices.

A direct approach to estimation of the age distribution is to actually attempt to count the number of units of each class sold in each year. An indirect approach is to relate the number of units sold to a region's population, gross national product, population density, number of vehicles, and/or number of highway miles. A combination of direct and indirect methods might be employed. However by some means it is necessary to estimate for each year the actual number of units sold in order to obtain an age distribution in absolute terms, in the same way that a population census requires an actual population count.

4.4 Approximating Age Distributions from DOC Files

For each of the five district offices and three frequency bands referred to in Section I, DOC's computer printouts list by SIC (Standard Industry Classification) code and by year of initial licensing (subject to variations to be considered later) the number of mobiles including portables which remain licensed at the end of any given year; licenses are renewed annually. These printouts are obtained as an extract from DOC's computerized Integrated Radio Station Licence System (IRLS) and exist for all fiscal year



ends 1972 to 1978, inclusive. Some information is available for Land Stations but it is organized by latitude and longitude, not by District Office code.

Fig. 1 shows a typical listing of IRLS data, which is plotted in Fig. 2. The ordinate Q is plotted in logarithmic co-ordinates and represents the cumulative number of units shown in Fig. 1. Abscissa N represents the number of years N from a beginning year which in this example is 1965. The final year is Y ; in this example Y corresponds to 1977.

Also plotted on Fig. 2 is $A = dQ/dN$, where A corresponds to $A(N)$ in Fig. 1 and approximates a snapshot of the (uncorrected) age distribution of the number of mobile units initially licensed in year N and remaining in service to the final year Y . (Because the first year (1964) includes equipment licensed up to and including 1964, $N=1$ corresponds to 1965). Thus, A approximates the mobile equipment inventory age distribution, including depreciation. Our measure of depreciation is the fraction of units in any given year which are discarded or for other reasons are not relicensed. Non-renewal of licenses has been referred to as the "cancellation problem". For our purposes cancellation appears to be a potential benefit rather than a problem since it enables depreciation to be automatically incorporated into our estimated age distribution.

Unfortunately, the age distribution estimated using DOC license files can be expected to differ from the actual (depreciated) distribution for various reasons including the following:

1. Equipment not yet sold, or sold but not yet licensed would be excluded from the inventory.
2. In cases where a licensee sells his equipment as second-hand the buyer would license it in the year of transfer which could be many years later than the year of initial sale. The effect on the age distribution estimates would depend on whether or not the seller replaced his sold equipment, and if he did whether or not notification of such replacement was given to DOC and incorporated in the computer files.



3. During any given year licenses may be moved from one district file to another, either because of regional boundary changes, (including of opening of new district DOC offices) or because the user himself moves to a new region of operation. The result would be a double counting of licenses in the year in which the move occurred.
4. Until a few years ago, a license amendment often resulted in replacement of the original license date by the amended date, particularly when a new frequency was added.
5. In one SIC category, namely municipal government services, one license is issued for an unspecified number of mobile units. However, upon investigation it was found that this was not really a problem.

The effect of item 1 would be to underestimate the mobile inventory, particularly in the current fiscal year. The problem is obviated by extrapolation of data for earlier years or by excluding the current fiscal year (for which DOC data is unavailable in any case). The effect of items 2 and 4 would be to understate age distributions in early years and to overstate distributions in later years. Item 3 would result in an overstatement of inventory, while item 5 would understate the inventory in municipal SIC categories.

4.5 Use of Age Distributions and Per Unit Equipment Costs to Determine Inventory Valuations

Assume for the moment that the age distribution $A(N)$ in Fig. 2 represents the actual number units sold in year N and still operational in final year Y , and that the per-unit cost $U(N)$ in year N is the same for all units. Define the (undepreciated) number of units sold in year N as $M(N)$. Define the annual depreciation rate as d , which is constant from year to year.

The NPV at the end of year Y is

$$NPV = \sum_{N=-\infty}^Y U(N)M(N)(1-d)^{Y-N} \quad (1)$$



The fact that the sum begins with $N = -\infty$ means that $M(N) = 0$ except for the past few decades.

The sum in (1) may be replaced by an integral, in which case N is a continuous variable:

$$NPV = \int_{N=-\infty}^Y U(N)M(N)(1-d)^{Y-N}dN \quad (2)$$

As noted earlier, available DOC printouts actually yield an estimate of the net number of units currently in service $A(N) = M(N)(1-d)^{Y-N}$; thus

$$NPV = \int_{-\infty}^Y U(N)A(N)dN \quad (3)$$

Determination of NPV based on $U(N)$ expressed in dollar values at year N is readily obtained once the initial price per unit $U(N)$ and depreciated age distribution $A(N)$ are known.

One can also determine NPVF using per unit costs $UF(N)$ which are based on year Y dollars. Determination of $UF(N)$ in terms of $U(N)$ requires knowledge of the inflation rate over the years following manufacture. Define the inflation rate for year N as $i(N)$. Then

$$UF(N) = U(N) \prod_{k=N}^{Y-1} [1 + i(k)] \quad (4)$$

If the inflation rate is constant at i over the years from N to $Y-1$ inclusive then

$$UF(N) = U(N)(1+i)^{Y-N} \quad (5)$$

and

$$NPVF = \int_{-\infty}^Y U(N)(1+i)^{Y-N}A(N)dN \quad (6)$$



Define the scrap value of units manufactured during year N as $S(N)$, and the replacement cost of these units as $R(N)$. Then the scrap value SV and the replacement value RC of the mobile inventory is

$$SV = \int_{-\infty}^Y S(N) A(N) dN \quad (7)$$

$$RC = \int_{-\infty}^Y R(N) A(N) dN \quad (8)$$

If $S(N)$ and $R(N)$ are independent of N , the year of manufacture, then

$$SV = S \int_{-\infty}^Y A(N) dN = S Q(Y) \quad (9)$$

$$RC = R \int_{-\infty}^Y A(N) dN = R Q(Y) \quad (10)$$

where S and R are the per-unit scrap values and replacement values, respectively and $Q(Y)$ is the total number of units in service at the end of year Y .

The average age \bar{A} of the mobile inventory can be calculated as follows:

$$\bar{A} = \int_{-\infty}^Y (Y-N) A(N) dN \quad (11)$$

$$= YQ(Y) - \int_{-\infty}^Y N A(N) dN$$



4.6 Fitting Age Distributions and Per-Unit Cost Data with Continuous Curves

Calculation of NPV, NPVF, SV and RV is greatly simplified if $A(N)$ (or $M(N)$), $U(N)$, $S(N)$, and $R(N)$ can be approximated by known functions. In addition, the parameters which define the known functions can be the basis on which age distributions for various geographic regions and frequency bands are compared. Finally the parameters, or more precisely the estimates thereof, can be used to specify confidence limits for NPV, NPVF, SV and RC.

Existing data from DOC files, examples of which are shown in Figs. 1 and 2, appear to be well fitted by straight lines of the form

$$\log_{10} Q = \log_{10} Q_0 + \alpha N \quad (12)$$

which yields

$$Q = Q_0 10^{\alpha N} \quad (13a)$$

$$= Q_0 e^{\beta N} \quad (13b)$$

where

$$\beta = (\log_e 10) \alpha = 2.30 \alpha \quad (13c)$$

Since $A(N) = dQ/dN$

$$A = A_0 e^{\beta N} \quad (14)$$

where $A_0 = \beta Q_0$. Recall that $A(N)$ is the depreciated age distribution of equipment, and that for a constant depreciation rate the actual age distribution $M(N) = A(N)/(1-d)^{Y-N}$. From (14) one obtains

$$M(N) = [A_0 / (1-d)^Y] [e^{\beta (1-d)}]^N = M_0 e^{\delta N} \quad (15)$$

where $M_0 = A_0 / (1-d)^Y$ and $\delta = \beta + \log_e (1-d)$.



From (15) which is based on our preliminary analysis of the mobile inventory data, one sees that the mobile inventory growth over the past two decades has been exponential, which is the usual prevailing growth patterns of a population in its early stages of development. The constants A_0 and β are readily obtained from Q_0 and α which correspond, respectively to the $N=0$ intercept and the slope of the line $A(N)$ fitting the cumulative inventory data obtained from DOE data files.

Sales data from manufacturers is expected to be available for estimation of per-unit costs of mobile equipment. Preliminary evaluations of data from one large manufacturer indicates that per-unit prices increase at a constant annual rate over the previous year's price in which case

$$U(N) = U_0 e^{\phi N} \quad (16)$$

From (16), (14) and (3) one obtains

$$\begin{aligned} \text{NPV} &= \int_{-\infty}^Y (U_0 e^{\phi N}) (A_0 e^{\beta N}) dN \\ &= U_0 e^{\phi Y} A_0 e^{\beta Y} / (\phi + \beta) \\ &= U(Y) A(Y) / (\phi + \beta) \end{aligned} \quad (17a)$$

If the inflation rate is also constant at i then

$$\begin{aligned} \text{NPVF} &= \int_{-\infty}^Y U_0 e^{\phi N} A_0 e^{\beta N} (1+i)^{Y-N} dN \\ &= U(Y) A(Y) / [\phi + \beta - \log_e(1+i)] \end{aligned} \quad (17b)$$

Equation (17) is in a particularly convenient form for calculation. NPV depends only on the final year intercepts $U(Y)$ of the per-unit price data and $A(Y)$ of the age distribution, together with growth constants β and ϕ as measured by logarithmic line slopes. NPVF depends on one additional factor, the inflation rate i and is obtained from NPV as follows

$$\text{NPVF} = \text{NPV}(\phi + \beta) / [\phi + \beta - \log_e(1+i)] \quad (17c)$$



If the per-unit price or age distribution curves were not well approximated by exponentials then NPV would have to be calculated using (3), possibly with the help of numerical integration techniques.

Use of (14) with $A(N) = dQ/dN$ yields $Q(Y) = A(Y)/\beta$, which upon substitution into (9) and (10) yields

$$SV = S[A(Y)/\beta] \quad (18a)$$

$$RC = R[A(Y)/\beta] \quad (18b)$$

If the inflation rate is not well approximated as being constant over the Y years of interest then evaluation of NPV and NPVF must be performed using (3), (4), (5) and (6).

One question that immediately arises is whether or not the mobile inventory in the various regions and SIC categories have the same growth rates. If they do not then the overall inventory growth rate will not be exponential. Consider for example two inventory categories with (depreciated) age distributions as follows:

$$A_1 = A_{10} e^{\beta_1 N} \quad (19a)$$

$$A_2 = A_{20} e^{\beta_2 N} \quad (19b)$$

Then the composite age distribution

$$\begin{aligned} A &= A_1 + A_2 \\ &= (A_{10} + A_{20} e^{\Delta N}) e^{\beta_1 N} \end{aligned} \quad (20)$$

where $\Delta = \beta_2 - \beta_1$ is the difference in the growth rates. Unless $\Delta = 0$, A is not a true exponential. If Δ is small relative to β_1 , then $\beta_1 \approx \beta_2$ and the composite depreciated growth rate is closely approximated by exponential behaviour.



The undepreciated growth constant γ in (15), the depreciated growth constant β and the depreciation rate d are related by

$$\gamma = \beta + \log_e(1 - d) \quad (21)$$

Thus, if β_1 and β_2 for two different age distributions differ, it may be because $\gamma_1 \approx \gamma_2$ and $d_1 \neq d_2$; i.e. the depreciation rates are different. Comments from those familiar with mobile equipment user groups indicate that depreciation d is different for different groups. Estimates of d for each group can be obtained from DOC data files which show year-to-year license cancellations. These estimates of d together with those for β could be used to determine γ . Comparison of γ , β and d among different regions and SIC categories may be of interest. To facilitate calculation of NPV, NPVF, SV and RC merging of various SIC categories is envisioned. Since the data points on graphs like the one in Fig. 2 are to be fitted by straight lines, categories to be merged should have similar (depreciated) growth rates. If it can be established that the undepreciated growth rate γ for the categories under consideration are equal, merging should be based on categories with equal depreciation rates d .

4.7 Estimation of NPV using Age Distributions and Per-Unit Equipment Costs

Until now it has been tacitly assumed that all inventory units in any given year have identical per-unit costs. In fact the per-unit costs of various units will be different. The costs of vehicle-mounted mobiles, portables and base stations constitute three classes with different costs, and within each category cost variations would also occur.



Consider C equipment classes (in the above paragraph $C = 3$) and let $U_{ij}(N)$ be the sale price in year N a particular unit i in class j . Then

$$NPV = \sum_{j=1}^C \left(\sum_{N=-\infty}^Y \left[\sum_{i=1}^{A_j(N)} U_{ij}(N) \right] \right) \quad (22)$$

where $A_j(N)$ is the (depreciated) age distribution for class j . Define

$$U_j(N) = \sum_{i=1}^{A_j(N)} U_{ij}(N) / A_j(N) \quad (23)$$

Thus, $U_j(N)$ is the average per-unit cost of class j equipment in year N .

To see the effects of errors in estimating $U_j(N)$ as well as $A_j(N)$ we write

$$U_{ij}(N) = \tilde{U}_j(N) + \Delta U_{ij}(N) \quad (24)$$

$$A_j(N) = \tilde{A}_j(N) + \Delta A_j(N) \quad (25)$$

where $\tilde{U}_j(N)$ and $\tilde{A}_j(N)$ denote estimates of $U_j(N)$ and $A_j(N)$ respectively, and ΔU_{ij} and ΔA_j are estimation errors. Then

$$\begin{aligned} NPV &= \sum_{j=1}^C \left(\sum_{N=-\infty}^Y \left[\sum_{i=1}^{\tilde{A}_j(N) + \Delta A_j(N)} \tilde{U}_j(N) + \Delta U_{ij}(N) \right] \right) \\ &= \sum_{j=1}^C \left(\sum_{N=-\infty}^Y \left[\tilde{U}_j(N) (\tilde{A}_j(N) + \Delta A_j(N)) + \sum_{i=1}^{\tilde{A}_j(N) + \Delta A_j(N)} \Delta U_{ij}(N) \right] \right) \\ &= \tilde{NPV} + \mathcal{E}_{NPV} \end{aligned} \quad (26)$$

where

$$\tilde{NPV} = \sum_{j=1}^C \left(\sum_{N=-\infty}^Y \tilde{U}_j(N) \tilde{A}_j(N) \right) \quad (27)$$

and

$$\mathcal{E}_{NPV} = \sum_{j=1}^C \left(\sum_{N=-\infty}^Y \left[\tilde{U}_j(N) \Delta A_j(N) \right] + \sum_{i=1}^{\tilde{A}_j(N) + \Delta A_j(N)} \Delta U_{ij}(N) \right) \quad (28)$$

Thus, \tilde{NPV} represent our estimate of NPV and \mathcal{E}_{NPV} is the estimation error.



Define

$$\sum_{i=1}^{\tilde{A}_j(N) + \Delta A_j(N)} \Delta U_{ij}(N) = (\tilde{A}_j(N) + \Delta A_j(N)) \Delta U_j(N) \quad (29)$$

in which case ΔU_j is the average error in estimating the year - N per-unit price of equipment class j.

Then

$$\begin{aligned} \epsilon_{NPV} &= \sum_{j=1}^C \sum_{N=-\infty}^Y \tilde{U}_j(N) \tilde{A}_j(N) \left[\frac{\Delta A_j(N)}{\tilde{A}_j(N)} + \frac{\Delta U_j(N)}{\tilde{U}_j(N)} + \frac{\Delta A_j(N)}{\tilde{A}_j(N)} \cdot \frac{\Delta U_j(N)}{\tilde{U}_j(N)} \right] \\ &= \sum_{j=1}^C \sum_{N=-\infty}^Y \tilde{U}_j(N) \tilde{A}_j(N) [\delta A_j(N) + \delta U_j(N) + \delta A_j(N) \delta U_j(N)] \quad (30) \end{aligned}$$

where $\delta A_j(N) = \Delta A_j(N) / \tilde{A}_j(N)$ and $\delta U_j(N) = \Delta U_j(N) / \tilde{U}_j(N)$

Thus $\delta A_j(N)$ and $\delta U_j(N)$ are estimations errors relative to the estimates themselves.

The following conclusions regarding the accuracy of the estimation of NPV emerge from (30):

1. Errors in estimating age distributions weigh equally with errors in estimating per-unit equipment costs in contributing to NPV estimation errors.
2. Errors in any year N and any category j are multiplied by the contribution $\tilde{U}_j(N) \tilde{A}_j(N)$ to NPV. The importance of accurately estimating this quantity increases with the quantity itself.
3. It is desirable to keep $\delta U_j(N)$ small. To do so requires that equipment classes be grouped in such a way that intra-class cost variations are minimal.
4. It is desirable to keep $\delta A_j(N)$ small. To do so requires that SIC categories be grouped to enable $A_j(N)$ to be well fitted by a straight line.



To determine the confidence of the estimate \widetilde{NPV} of the actual net present value, one would assume $\widetilde{A}_j(N)$ and $\widetilde{U}_j(N)$ to be uncorrelated zero-mean Gaussian random variables with variances $\sigma_{A_j(N)}^2$ and $\sigma_{U_j(N)}^2$, in which case

$$\sigma_{NPV}^2 = \sum_{j=1}^C \sum_{N=-\infty}^Y \widetilde{U}_j(N) \widetilde{A}_j(N) [\sigma_{A_j(N)}^2 + \sigma_{U_j(N)}^2 + \sigma_{A_j(N)}^2 \cdot \sigma_{U_j(N)}^2] \quad (31)$$

For further simplification one would normally assume $\sigma_{A_j(N)}^2 = \sigma_{A_j}^2$ and $\sigma_{U_j(N)}^2 = \sigma_{U_j}^2$ in which case

$$\sigma_{NPV}^2 = \sum_{j=1}^C \widetilde{NPV} [\sigma_{A_j}^2 + \sigma_{U_j}^2 + \sigma_{A_j}^2 \sigma_{U_j}^2] \quad (32)$$

Thus, the estimate of each equipment category's NPV estimate, age distribution variance $\sigma_{A_j}^2$ and cost variance $\sigma_{U_j}^2$ is all that is required to estimate the variance σ_{NPV}^2 , knowledge of which can then be used to determine the confidence of \widetilde{NPV} using either the normal distribution or t-distribution as appropriate.

In fact, least squares fits (or weighted least squared fits) to the points defining $\widetilde{A}_j(N)$ and $\widetilde{U}_j(N)$ are standard computer routines; the numbers used to determine these fits, namely the samples of $A_j(N)$ from DOC data files and the samples of $U_j(N)$ from manufacturers can then be used directly to calculate $\sigma_{A_j}^2$ and $\sigma_{U_j}^2$, as well as the parameters used to define $\widetilde{A}_j(N)$ and $\widetilde{U}_j(N)$. Existing data indicates that $\widetilde{A}_j(N)$ and $\widetilde{U}_j(N)$ are exponential with two parameters.

We note that \widetilde{NPV} in (27) can be represented by an integral as follows:

$$\widetilde{NPV} = \sum_{j=1}^C \int_{-\infty}^Y \widetilde{U}_j(N) \widetilde{A}_j(N) dN \quad (33)$$

Similarly

$$\widetilde{NPVF} = \sum_{j=1}^C \int_{-\infty}^Y \widetilde{U}_j(N) \left[\prod_{k=N}^{Y-1} (1 + \widetilde{i}(k)) \right] \widetilde{A}_j(N) dN \quad (34)$$

where $\widetilde{i}(k)$ is the estimated inflation rate for year k.



$$\tilde{SV} = \int_{-\infty}^Y \tilde{S}(N) \tilde{A}(N) dN$$

(35)

$$\tilde{RC} = \int_{-\infty}^Y \tilde{R}(N) \tilde{A}(N) dN$$

(36)

The errors of estimation of these various quantities are determined using the approach used to determine σ_{NPV}^2 .

Use of simple functions to approximate $U_j(N)$ and $A_j(N)$ means that NPV, NPVF, SV and RC are estimated without resorting to tedious numerical calculations. If computer routines are used to fit the data points, confidence limits are readily obtained for the economic quantities of interest. Data used to obtain $\tilde{U}_j(N)$ would also be used to determine per-unit scrap values $\tilde{S}(N)$ and per-unit replacement costs $\tilde{R}(N)$.

4.8 Approach to Land Mobile Inventory Estimation - Summary

It appears that DOC files can be used to estimate age distributions of various categories of mobile equipment. It is anticipated that per-unit prices would be obtainable from manufacturers. Estimation of the net present value for a given geographic region and band involves the following tasks:

1. In each geographic region and frequency band, SIC categories should be grouped on the basis of similar depreciated growth rates β . While precise definition of the term "similar" is possible, expediency would probably require that the judgement be on the basis of visual fits to straight lines of uncorrected DOC file data like that in Fig. 1 and 2, and corroborated by those familiar with industry growth and depreciation trends.



2. The depreciated growth rate $A(N)$ is next determined for each geographic region and frequency band and for each merged SIC category. There are two methods to determine $A(N)$. One involves fitting data points from DOC files by straight lines based either on visual fits or computer routines; visual fits are quick but computer routines are more precise and provide for relatively easy determination of error variances which lead ultimately to confidence limits on the estimated economic quantities. A second approach is to use only most-recent-year file data for each year to obtain $M_j(N)$ the undepreciated age distribution, and to then use files for successive years (eg. 1963 - 1976, 1964 - 1977, 1965 - 1978) together with experience to estimate depreciation rates d_j for each equipment class j ; then $A_j(N) = M_j(N)/(1-d_j)^{Y-N}$. Both approaches could be used and compared. Budget constraints would probably dictate use of the first method, possibly with use of the second for a few spot crosschecks. Selection of the depreciation rate poses somewhat of a dilemma. One could use either the rate actually estimated from DOC files which rate then corresponds to the fraction of units removed from service each year, or that rate permitted under the income tax act, or some other rate. We would advocate use of rates based on actual removal of equipment from service.
3. Costs of equipment $U_j(N)$ would next be estimated and expressed in terms of parameters defining simple curves, after the equipment categories had been established on the basis of similar cost trends. Specifically with $U_j(N) = U_{j0} e^{\theta_j N}$, the parameters of interest would be constant U_{j0} and cost growth rate θ_j for class j . Again the definition of "similar" would probably be on the basis of visual examination of cost data.
4. Equations describing $\tilde{U}_j(N)$ and $\tilde{A}_j(N)$ would then be substituted into (33) to determine NPV as follows:

$$\tilde{NPV} = \sum_{j=1}^C \tilde{U}_j(Y) \tilde{A}_j(Y) / (\tilde{\phi}_j + \tilde{\beta}_j) \quad (37)$$



5. The accuracy of the economic estimates (in this case \widetilde{NPV}) would be determined either by well established formal procedures if computer fits of curves to dates were used, by hand-held calculator procedures if visual fits of data points were used, or by visual examination of spreads of date points used to obtain fits describing $\widetilde{A}_j(N)$ and $\widetilde{U}_j(N)$. This latter approach is based on the following relation:

$$|\varepsilon_{NPV}| \leq \sum_{j=1}^C \widetilde{NPV}_j [|\delta A_j| + |\delta U_j| + |\delta A_j| \cdot |\delta U_j|] \quad (38)$$

"Typical values" could be used for $|\delta A_j|$ and $|\delta U_j|$. This approach is quick but not very reliable. An alternative would be to calculate confidence limits for the NPV estimates for a few geographic regions, frequency bands and equipment classes, in order to obtain an indication of the accuracy of these estimates.

An approach similar to the one above is appropriate to determination of \widetilde{NPVF} , \widetilde{SV} (scrap values) and \widetilde{RC} replacement costs. Estimation of NPVF requires estimation of the inflation rate over the past several years as explained earlier. If the inflation rate over the years of interest is constant at i then

$$\widetilde{NPVF} = \sum_{j=1}^C \widetilde{U}_j(Y) \widetilde{A}_j(Y) / [\widetilde{\phi}_j + \widetilde{\beta}_j - \log_e(1+i)] \quad (39)$$

4.9 Weaknesses of the Proposed Estimation Procedure

The weaknesses of the procedure for estimating the economic quantities of interest are as follows:

1. Errors in the DOC files used to obtain the age distribution $A_j(N)$ or $M_j(N)$ are not easily corrected. To correct for second-hand (or reconditioned) equipment licensed as new would seem to require (prohibitively) elaborate efforts and would probably involve interviewing users.



2. DOC file printouts do not differentiate between vehicle mounted mobiles and portables. If the cost distributions $U_j(N)$ are significantly different for these two classes, (in actual fact it was found that price differential is minor) some estimate would have to be made regarding the proportion of mobiles and portables in each SIC category, region and frequency band, and any difference in depreciated growth rates would have to be accounted for. Some estimates of non-portable/portable ratios would be available from DOC's data base. Obtaining and processing such data could be tedious, but there may be no alternative.

3. Correcting of municipal SIC category age distributions (actually found to be quite accurate) seems essential in view of the fact that one license may correspond to many equipment units. Municipalities seem willing and able to provide fairly reliable estimates of the actual number of units in operation, but there may be some difficulty in estimating the age distribution of these units.

Notwithstanding these weaknesses, the procedure proposed in this report appears practicable, and seems well suited to the available data and budgeted level of effort.



5.0 SYSTEM EVALUATION

This section takes the data accumulated from the sources listed in Section 3.0 and applies the analysis methods described in Section 4.0 to arrive at: Net Present Value, Net Present Value in 1978 dollars, Salvage Value and Replacement Cost for the Land Mobile Inventory.

Using the data from Table 01 (example of which is shown in Figure 1) for all district offices, SIC categories and frequency bands, plots have been developed in Appendix III of the yearly variation in mobile population from 1968 through 1978. On each plot a straight line approximation has been made producing an intercept for the year 1978 and a slope of β . The intercept represents the snapshot of the uncorrected age distribution of the number of mobiles and portables licenced in that year.

The financial analyses evolve in Tables 3 through 7 and descriptions of the development of each follow.

5.1 Age Distribution Summary by Sequential SIC Code (Table 3)

Table 3 summarizes the constants $A(78)$ and β determined from the yearly variation plots in Appendix III by sequential SIC numbers for each of the five district offices. This is the working table for subsequent tabulation and calculation for Mobiles and Portables.

5.2 Age Distribution Summary by Depreciation Group (Table 4)

This analysis follows the age distribution fitting procedures described in Section 4.6.



In this table, the contents of Table 3 have been rearranged such that the depreciated growth constant, β , is in ascending order. Groups of β were then established with a maximum +12% variation, enabling a reduction in the number of calculations to be performed to calculate Net Present Value and other financial quantities. These groups are identified in Table 4 as A, B, C, D & E. The +12% limit represents a balance between a manageable number of depreciation categories versus an increase in error which would result from a further reduction in the number of categories.

Once the depreciation groups were established, weighted depreciation growth constants were calculated by dividing the sum of the products of $A(78)\beta$ for each SIC point in the group, by the sum of $A(78)$ for each SIC category in the group. It will be noted that the maximum number of depreciation groups for any district office is five (group A through E inclusive).

Finally, the depreciation group $A(78)$ represents the sum of the $A(78)$ quantities for each SIC category within the group.

With reference to the graphs plotted in Appendix III, an interesting result arises. For those SIC categories where there has been substantial data and points have close approximation to a straight line, γ has been plotted on the same graph, representing the undepreciated growth constant. These points were plotted from the final year net additions for the fiscal year Table 01's for 1972 through 1978 inclusive. Using equation 15 from Section 4.0, restructured to find d , it has been found that d approximates a depreciation rate of 20% in most instances, though it is as low as 8% for the transportation category and is as high as 32% for construction and other SIC categories. This provides a very nice check of the validity on using Table 01 for age distribution.



5.3 Financial Analysis Summary, Mobiles/Portables (Table 5)

Calculations for NPV, NPVF, SV and RC have been performed on the data included in Table 4, using the formulae (17a), (17b), (18a) and (18b) in Section 4.0. The dollar values have been sub-totalled for district offices and frequency bands. The adjustment for price escalation was used on the basis of Consumer Price Index.

5.4 Financial Analysis Summary, Land Stations (Table 6)

To enable financial calculations for Land Stations, a depreciation rate of 10% has been used, enabling the calculation of the depreciated growth constant β . A figure of 10% has been arrived at after consultation with mobile manufacturers and major users. It is lower than the depreciation for Mobiles, due to the fact that Land Stations are normally stationary and are not subject to the same potential for theft and damage. Using the formula $\gamma = \beta + \log_e (1-d)$ (See Section 4.6), has been calculated for use throughout all frequency bands and district offices. Calculations for NPV, NPVF, SV and RC have then been performed using the formulae (17a), (17b), (18a) and (18b) in Section 4.0, as for Section 5.3. The appropriate slopes (ϕ) and 1978 intercepts $Y(U)$ have been taken from the costing analysis. $A(Y)$ has been taken as 10% of the total of Mobiles plus Portables.

As with Mobiles and Portables, sub-totals are given for both frequency bands and all district offices.

5.5 Financial Analysis Summary, Band 410-420 MHz (Table 7)

Up to this point it would appear that little attention has been paid to the 410 - 420 MHz band. Investigation of the company code files and the IRLS show that this band accounts for only 2.4% of the total inventory (in units)



in the five district offices. Due to the limited data available, it is not realistic to calculate β from slope characteristics of the age distributions. Due to the fact that the growth of this band has not been used up until 1972, only replacement cost and salvage value have been calculated for this category, using cumulative quantities at the year end 1978. These quantities for Mobiles/Portables and Land Stations for the various District Offices are summarized in Table 10. With reference to this frequency band, it is felt that a meaningful age distribution could only be developed following a user survey - probably not a very extensive task due to the limited number of licencees at the present time. In Table 7, Q(78) represents the total quantity of land mobile stations at the end of fiscal year 1978. For Mobiles and Portables this represents the cumulative quantities shown in Table 01. For Land Stations, quantities have been taken at the rate of 10% of Mobiles plus Portables.

Salvage value and replacement cost have been calculated using the cost factors from the costing analysis for the appropriate band and formulas (17a), (17b), (18a) and (18b) of Section 4.0



6.0 ECONOMICS OF TECHNICAL CHANGE

This section is devoted to estimated cost to the users for making certain technical changes in their equipment. The changes anticipated are:

- a) Change of frequency band from VHF to UHF or vice versa.
- b) Improvement of technical specifications, including intermodulation and selectivity characteristics.
- c) Change in the bandwidth characteristics, eg. from 30 kHz to 15 kHz in the VHF and 25 kHz to 12.5 kHz in the UHF bands.
- d) Major frequency change within the VHF or UHF band, eg. 138-150 MHz to 150-174 MHz, or 410-420 MHz to 450-470 MHz.
- e) Minor frequency change in the VHF or UHF band, eg. a change within the 150-174 MHz, 410-420 MHz or 450-470 MHz frequencies.

There may be other possible technical changes perhaps relevant to this study, however the above represents a broad cross section of potential approaches.

The cost of the frequency changes which appear to be feasible amongst the following items are summarized in Table 8.

6.1 Change of Frequency Band From VHF to UHF or Vice Versa

The cost of changing a Mobile frequency from VHF to UHF or vice versa is prohibitive. The major mobile manufacturers advise that the cost of such a change would probably exceed the cost of purchasing a new radio.

6.2 Improvement of Technical Specifications, Including Intermodulation and Selectivity Characteristics

Substantial R & D effort would be required to bring about improved radio characteristics such as frequency stability, intermodulation characteristics, spurious rejection, frequency response, harmonic distortion and other



parameters affecting the overall operation of the radio. Within the framework of this study it has not been possible to determine development costs and projected modification costs for such changes.

6.3 Change in the Bandwidth Characteristics

At one time the channel spacing in the VHF band was 120 kHz. Suppliers of Mobile equipment were required to reduce this spacing to 60 kHz and finally to 30 kHz and appropriate design and retrofit arrangements were carried out. There may be instances where a further reduction 12.5 kHz may be conceivable and costs have been developed for such a bandwidth reduction. It is conceivable that a further reduction of 50% could be implemented, though such a change would be subject to frequency response degradation as well as limitations in data speed capability and threshold capability due to reduced deviations.

A rough estimate of the cost of such a change, assuming R & D could be amortized over a minimum of 1,000 Mobiles and Land Stations, would be \$300.00 per radio. Based on the 1978 cumulative quantities of Mobiles, Portables and Land Stations in each district office, the total estimated cost would be as shown in Table 8.

6.4 Major Frequency Change Within the VHF or UHF Band

A change of frequency from the 138 - 150 band to the 150 - 174 band, or from the 410 - 420 MHz band to the 450 - 470 MHz band is technically possible, though more difficult than a change of frequency within one band.

Estimates for conversion run from \$250.00 to \$350.00 per Mobile and calculations for the total costs incurred by licencees for each district office are as per Table 8 based on the upper cost of \$350.00 per Mobile. When talking of frequency changes, it is important to note that these represent average costs for frequency changes and provide for any number of frequency changes within a given radio.



6.5 Minor Frequency Change in the VHF or UHF Band

Technically, this represents the simplest change, though in terms of relieving frequency congestion, such a change would probably not offer any major advantages.

The cost varies from \$100.00 to \$200.00 depending on whether quartz crystals or integrated circuit oscillator modules are used and, for purposes of cost estimates in Table 8, the upper limit of \$200.00 has been used.



7.0 DATA BASE RECOMMENDATIONS

Generally speaking, Cantel project personnel were impressed with the manner in which the five district offices visited maintain and operate their respective data bases. Contact with municipal administrations in Vancouver, Edmonton, Calgary, Lethbridge, Toronto and Cobourg verified a high accuracy in the IRLS insofar as quantities of Mobiles and Land Stations are concerned.

There are perhaps two possible changes in the system which would provide better information over the age distribution of the inventory. First, it may be desirable to request all suppliers of Mobile equipment in Canada to affix a computer-type card to each radio prior to shipment, which could easily be removed by the user, completed and inserted in a self-addressed envelope to be returned to the Department. This card could show the following minimum information:

- Manufacturer name and model number
- DOC type approval number
- Transmit frequencies
- Receive frequencies
- Power
- Name of Licencee
- Address
- Date received
- Signature

The first five items above would be completed by the manufacturer: the latter items would be completed by the licensee. It is not intended that this card substitute for a licence application, but would provide verification that the equipment put into service is as per the original application.



Second, a useful feedback element providing an indication of service period might be an additional, perforated form appended to the bottom of each licence. This would take the form of a "Notification of Withdrawal from Service" form and minimum information could include:

Date of withdrawal
Reason for withdrawal
If sold, for what price

Realizing that the last item above might be a sensitive question, this could be left optional.

It is felt that the above minor changes to the present system would not inconvenience the users to any significant extent and would greatly improve the measure of Canada's Mobile Inventory, in spite of the fact that it would probably be at least ten years before its value could be achieved.

With regard to municipal licencees, the present technique of issuing one licence for any number of Mobiles does not appear to produce any more quantitative errors than multi-licencing for other users.

Finally, a few comments are added on approaches that would be taken to this study if it were to be done over again. Specifically:

- i) In view of the difficulty of receiving an official response from mobile manufacturers, questions associated with quantities sold would probably be eliminated and a greater effort would be made in establishing pricing structures on an age-distributed basis.
- ii) The questions discussed above would be sent to all mobile manufacturers, estimated to supply at least 5 or more percent of the overall market. Visits would only be made if required.



- iii) Visits to District Offices would perhaps be limited to two, since it was found that the IRLS is much more accurate than was originally anticipated. Principal information to be gained from company code files would include: sampling of the quantities of Land Stations versus Mobiles and Portables, and a detailed evaluation of the files for a few representative, large municipalities.



8.0 REFERENCES

The following is a list of reference material that has been used to support the work undertaken in this study.

- 8.1 Radio equipment list, issue 7, January 1979
- 8.2 Computer output microfilm publication which indicates DFL and IRLS reports produced by DOC.
- 8.3 A study of user needs in mobile radio, Volume 1, main results by Harry Dulmage Associates Ltd.
- 8.4 Copy of letter to Mr. Tom Mimee, Manager of Electrical and Electronic Manufacturers Association of Canada.
- 8.5 Some information from the Department of Industry, Trade and Commerce regarding mobile telecommunications in Canada.
- 8.6 Computer Runs
 - Land Mobile Tables 01 and 13 for six district offices as of March, 1978.
 - Central Region Data Base, extracts from Edmonton and Calgary District Offices.
- 8.7 Microfiche report, 81, 82, 85 and 86.
- 8.8 Summaries of mobile and land stations by region and year, from 1972 through 1976.
- 8.9 Selected company code files from five district offices.



- 8.10 DOC fee schedule for 1979-80.
- 8.11 Demand for radio frequency spectrum workload and congestion report, Section 3 Radio Licence Data and its Reconstruction by Eric West.
- 8.12 DCB central system library notes.
- 8.13 Sector profile for mobile telecommunications in Canada only.
- 8.14 Statistics for LM Report System dated May 3, 1979 from E. Marquis.
- 8.15 Central Region VHF/UHF data base, data entry form field definitions.
- 8.16 SIC Codes (numerical listing).
- 8.17 DCB Central System Library.
- 8.18 List of RCCMRS operators (Edmonton)
- 8.19 List of RCCMRS operators (Vancouver)
- 8.20 List of RCCMRS operators (Montreal)
- 8.21 Instructions for VHF/UHF data input form and data update form (Pacific Region)
- 8.22 Survey of wide area of users of frequencies below 890 MHz in the Ontario region, June 15/78.
- 8.23 VHF/UHF data base data entry input field definitions (Ontario Region).
- 8.24 Liste d'attribution des Frequences (Partie VII).



8.25 Liste d'attribution des Frequences (Partie VIII).

8.26 Liste d'attribution des Frequences (Partie IX).

8.27 Liste d'attribution des Frequences (Appendice II).

8.28 Radio Equipment list (Issue 7).



THE NUMBER OF LAND MOBILES BY BAND AND YEAR.
SUMMARIZED BY SECTOR AND DISTRICT OFFICE

TABLE TYPE 01

DISTRICT OFFICE:
SECTOR:

BAND		TO 1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
	N		1	2	3	4	5	6	7	8	9	10	11	12	Y = 13
BAND 1 (27.2250 - 50.0000 MHZ)															
NET ADDITIONS		1	1	0	0	27	13	15	4	17	14	8	6	0	41
CUMULATIVE		1	2	2	2	29	42	57	61	78	92	100	106	106	147
BAND 2 (138.0000 - 150.0000 MHZ)															
NET ADDITIONS		0	0	0	0	6	1	5	34	9	0	18	43	0	0
CUMULATIVE		0	0	0	0	6	7	12	46	55	55	73	116	116	116
BAND 3 (150.0001 - 174.0000 MHZ)															
NET ADDITIONS	A(N)	727	38	169	192	130	212	261	315	397	419	328	335	449	199
CUMULATIVE	Q(N)	727	765	934	1126	1256	1468	1729	2044	2441	2860	3188	3523	3972	4171
BAND 4 (410.0000 - 421.0000 MHZ)															
NET ADDITIONS		0	0	0	0	0	0	0	0	0	0	0	0	0	0
CUMULATIVE		0	0	0	0	0	0	0	0	0	0	0	0	0	0
BAND 5 (450.0000 - 470.0000 MHZ)															
NET ADDITIONS		45	17	21	15	12	24	60	51	47	68	145	126	82	63
CUMULATIVE		45	62	83	98	110	134	194	245	292	360	505	631	713	776
TOTAL OVER ALL BANDS															
NET ADDITIONS		773	56	190	207	175	250	341	404	470	501	499	510	531	303
CUMULATIVES		773	829	1019	1226	1401	1651	1992	2396	2866	3367	3866	4376	4907	5210

Figure 1 EXTRACT FROM DOC FILES (TABLE 01)

Figure 2

YEARLY VARIATION IN MOBILE POPULATION

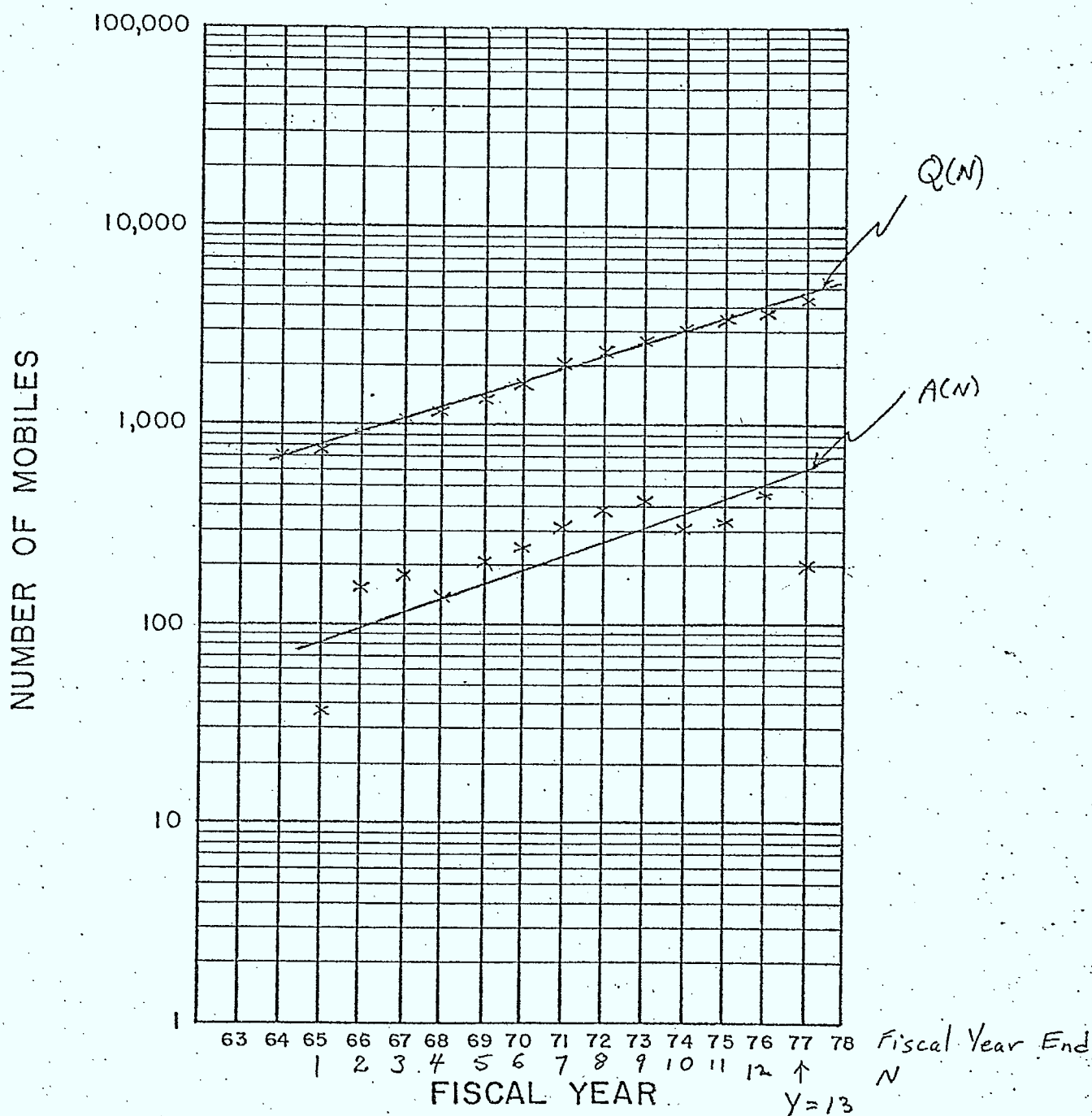
DISTRICT OFFICE: DATE: April 1979SECTOR: PREPARED BY: RWD.BAND: 3 (150-174 MHz) DRAWING No.: Figure 2

TABLE 1
SUBJECTIVE DEPRECIATION CATEGORIES

<u>Category</u>	<u>Write-off Period</u>	<u>*Approx. Quantity</u>
1	8 years	49%
2	5 years	45%
3	3.5 years	6%

*Expressed as a percentage of all Land Mobile Stations licenced in the 5 district offices.

	<u>SIC#</u>	<u>DESCRIPTION</u>
<u>CATEGORY 1</u>	01	Agriculture
	03	Fishing & Trapping
	07	Transportation & Storage
	08	Communications
	10	Trade
	11	Finance, Insurance & Real Estate
	12	Services
	16	Other
	17	Invalid SIC code
	18	No SIC code
<u>CATEGORY 2</u>	02	Forestry
	05	Manufacturing
	06	Construction
	09	Public Utilities
	13	Federal Administration
	14	Provincial Administration
	15	Local Administration
<u>CATEGORY 3</u>	04	Mining & Quarrying

TABLE 2

MUNICIPAL INVENTORY VERIFICATION SNAPSHOT

<u>LICENCEE</u>	<u>COMPANY CODE</u>	<u>IRLS QUANTITY Mobiles & Portables</u>	<u>ACTUAL QUANTITY Mobiles & Portables</u>	<u>ERROR (%)</u>
CITY OF CALGARY				
Fire & Ambulance	0874919	55	58	-5.2
Police	0800146	482	509	-5.3
Transit	0805282	313	507	*-38.3
Engineering	0804441	75	62	*+21.0
CITY OF EDMONTON				
Parks	0817557	82	80	+2.5
Engineering	0802513	192	188	+2.1
Sanitation	0862747	120	120	0
Power	0801351	205	220	-6.8
CITY OF LETHBRIDGE				
Police	0804644	42	40	+5.0
Electrical	0886520	17	23	-26.1
CITY OF VANCOUVER				
Fire	0800514	109	102	+6.9
Police	0800505	465	439	+5.9
COBOURG PUBLIC UTILITIES COMMISSION				
	0811459	6	6	0
COUNTY OF NORTHUMBERLAND				
	0871721	38	38	0
TORONTO HYDRO ELECTRIC SYSTEM				
	0800500	105	110	-4.5
TOWNSHIP OF YORK HYDRO SYSTEM				
	0801155	32	30	+6.7

*Possibility of overlap with other company codes.

TABLE 3

AGE DISTRIBUTION, SUMMARY BY SEQUENTIAL SIC CODE

150 - 174 MHz BAND

SIC#	SECTOR	(For Mobiles & Portables)									
		D.O.112 (VANCOUVER)		D.O.222 (EDMONTON)		D.O.223 (CALGARY)		D.O.422 (TORONTO)		D.O.552 (MONTREAL)	
		A(78)	β	A(78)	β	A(78)	β	A(78)	β	A(78)	β
01	Agriculture	15	0.293	200	0.427	200	0.461	46	0.194	12	0.222
02	Forestry	120	0.088	60	0.120	100	0.212	-	-	-	-
03	Fishing & Trapping	-	-	-	-	-	-	-	-	40	0.244
04	Mining & Quarrying	22	0.360	1200	0.379	1200	0.356	12	0.179	8	0.098
05	Manufacturing	90	0.094	380	0.311	200	0.300	150	0.098	160	0.139
06	Construction	200	0.190	820	0.307	720	0.358	180	0.094	250	0.127
07	Transport & Storage	750	0.143	950	0.247	1000	0.322	800	0.109	1300	0.161
08	Communications	70	0.085	87	0.078	130	0.288	200	0.092	150	0.092
09	Public Utilities	80	0.074	67	0.099	150	0.302	35	0.123	350	0.147
10	Trade	100	0.183	460	0.373	350	0.356	280	0.220	160	0.116
11	Finance, Insurance & Real Estate	37	0.361	150	0.501	100	0.691	95	0.281	23	0.349
12	Services	200	0.204	620	0.215	900	0.289	210	0.166	350	0.190
13	Federal Government	600	0.548	500	0.402	250	0.471	70	0.312	70	0.111
14	Provincial Government	60	0.432	300	0.351	70	0.286	50	0.312	-	-
15	Local Government	130	0.192	500	0.338	280	0.280	850	0.286	68	0.131
16	Other	60	0.445	-	-	-	-	-	-	-	-
17	Invalid SIC	-	-	-	-	-	-	-	-	-	-
18	No SIC	-	-	-	-	-	-	-	-	-	-

450 - 470 MHz BAND

01	Agriculture	2	0.069	10	0.230	11	0.275	24	0.226	4	0.174
02	Forestry	30	0.171	18	0.197	5	0.183	5	0.212	-	-
03	Fishing & Trapping	-	-	-	-	-	-	3	0.167	-	-
04	Mining & Quarrying	10	0.092	170	0.236	120	0.255	9	0.242	-	-
05	Manufacturing	80	0.182	80	0.290	50	0.204	300	0.380	120	0.156
06	Construction	100	0.202	300	0.461	160	0.328	200	0.259	260	0.279
07	Transport & Storage	160	0.182	100	0.147	42	0.175	600	0.340	420	0.213
08	Communication	70	0.176	100	0.183	70	0.310	170	0.292	150	0.325
09	Public Utilities	45	0.110	18	0.271	10	0.266	60	0.084	23	0.153
10	Trade	100	0.461	32	0.294	50	0.427	240	0.300	100	0.230
11	Finance, Insurance & Real Estate	45	0.362	27	0.450	20	0.266	90	0.432	20	0.306
12	Services	94	0.253	200	0.241	140	0.242	250	0.230	260	0.266
13	Federal Government	90	0.354	20	0.169	18	0.289	12	0.103	90	0.381
14	Provincial Government	20	0.300	85	0.426	20	0.310	12	0.222	-	-
15	Local Government	12	0.110	7	0.209	50	0.221	140	0.351	-	-
16	Other	-	-	-	-	-	-	-	-	-	-
17	Invalid SIC	-	-	-	-	-	-	-	-	-	-
18	No SIC	-	-	-	-	-	-	-	-	-	-

For explanation, see Section 5.1

(for Mobiles & Portables)

TABLE 4

AGE DISTRIBUTION SUMMARY BY DEPRECIATION GROUP

150 - 174 MHz BAND

DEPRECIATION GROUP	D.O.112 (VANCOUVER)					D.O.222 (EDMONTON)					D.O.223 (CALGARY)					D.O.442 (TORONTO)					D.O.552 (MONTREAL)				
	SIC	A(78)	β	COMBINED β	A(78)	SIC	A(78)	β	COMBINED β	A(78)	SIC	A(78)	β	COMBINED β	A(78)	SIC	A(78)	β	COMBINED β	A(78)	SIC	A(78)	β	COMBINED β	A(78)
A	09	80	0.074	-	-	08	87	0.078	0.078	87	02	100	0.212	0.212	100	08	200	0.092	-	-	15	68	0.031	0.031	68
	08	70	0.085	-	-											08	180	0.094	-	-					
	02	120	0.088	-	-											05	150	0.098	-	-					
	05	90	0.094	0.086	360											07	800	0.109	0.103	1330					
B	07	750	0.143	0.143	750	09	67	0.099	-	-	15	280	0.280	-	-	09	35	0.123	0.123	35	08	150	0.092	-	-
	02	60	0.120	0.109	127	08	130	0.288	-	-	08	70	0.286	-	-	04	8	0.098	-	-	04	8	0.098	-	-
	12	900	0.289	-	-	12	900	0.289	-	-	12	900	0.288	-	-	13	70	0.111	-	-	13	70	0.111	-	-
	05	200	0.302	-	-	05	200	0.302	-	-	05	200	0.302	-	-	10	160	0.116	0.105	388	10	160	0.116	0.105	388
	09	150	0.302	-	-	09	150	0.302	-	-	09	150	0.302	-	-	06	250	0.127	-	-	06	250	0.127	-	-
	07	1000	0.322	-	-	07	1000	0.322	-	-	07	1000	0.322	-	-	05	160	0.139	-	-	05	160	0.139	-	-
	04	1200	0.356	-	-	04	1200	0.356	-	-	04	1200	0.356	-	-	09	350	0.147	-	-	09	350	0.147	-	-
	10	350	0.356	-	-	10	350	0.356	-	-	10	350	0.356	-	-	07	1300	0.161	0.153	2060	07	1300	0.161	0.153	2060
	06	720	0.358	0.327	5000	06	720	0.358	0.327	5000	11	100	0.691	0.691	100	10	230	0.220	-	-	12	350	0.190	-	-
C	10	100	0.183	-	-	12	620	0.215	-	-	01	200	0.461	-	-	12	210	0.106	-	-	06	250	0.127	-	-
	06	200	0.190	-	-	07	950	0.247	0.234	1570	13	250	0.471	0.467	450	04	12	0.179	-	-	05	160	0.139	-	-
	15	130	0.192	-	-											01	46	0.194	0.171	268	09	350	0.147	-	-
	12	200	0.204	0.194	630																07	1300	0.161	0.153	2060
D	01	15	0.293	-	-	06	920	0.307	-	-	11	100	0.691	0.691	100	11	95	0.281	0.235	375	12	350	0.190	-	-
	04	22	0.380	-	-	05	380	0.311	-	-															
	11	37	0.361	0.347	74	15	500	0.338	-	-															
						14	300	0.351	-	-															
						10	460	0.373	-	-															
						04	1200	0.379	0.347	3660															
E	14	80	0.432	-	-	13	500	0.402	-	-	13	70	0.312	-	-	13	70	0.312	-	-	14	220	0.264	-	-
	16	60	0.445	-	-	01	200	0.427	-	-															
	13	600	0.548	0.530	720	11	150	0.501	0.425	850															

For explanation, See Sec. 5.2

TABLE (cont.)

AGE DISTRIBUTION SUMMARY BY DEPRECIATION GROUP

450 - 470 MHz

DEPRECIATION GROUP	D.O.112 (VANCOUVER)					D.O.222 (EDMONTON)					D.O.223 (CALGARY)					D.O.442 (TORONTO)					D.O.552 (MONTREAL)				
	SIC	A(78)	β	COMBINED β	A(78)	SIC	A(78)	β	COMBINED β	A(78)	SIC	A(78)	β	COMBINED β	A(78)	SIC	A(78)	β	COMBINED β	A(78)	SIC	A(78)	β	COMBINED β	A(78)
A	01	2	0.069	0.069	2	07	100	0.147	-	-	07	42	0.175	-	-	09	60	0.084	-	-	09	23	0.153	-	-
						13	20	0.169	-	-	02	5	0.183	-	-	13	12	0.103	0.087	72	05	120	0.156	-	-
						08	100	0.183	0.165	220	05	50	0.204	-	-						01	4	0.174	0.152	147
											15	50	0.221	0.201	147										
B	04	10	0.092	-	-	02	18	0.197	-	-	12	140	0.242	-	-	03	3	0.167	-	-	07	420	0.213	-	-
	09	45	0.110	-	-	15	7	0.209	-	-	04	120	0.255	-	-	02	5	0.212	0.195	8	12	250	0.266	-	-
	15	12	0.110	0.107	67	01	10	0.230	-	-	09	10	0.266	-	-						10	100	0.230	0.220	780
						04	170	0.236	-	-	11	20	0.266	-	-										
C						12	200	0.241	0.236	405	01	11	0.275	-	-	13	18	0.289	0.253	319					
	02	30	0.171	-	-	09	18	0.271	-	-	08	70	0.310	-	-	14	12	0.222	-	-	06	260	0.279	-	-
	08	70	0.176	-	-	05	80	0.290	-	-	14	20	0.310	-	-	01	24	0.226	-	-	11	20	0.306	-	-
	05	80	0.182	-	-	10	32	0.294	0.288	130	06	160	0.328	0.322	250	12	250	0.230	-	-	08	150	0.325	0.296	430
D	07	160	0.182	0.180	540											04	9	0.242	-	-					
																06	200	0.259	0.242	483					
	12	94	0.253	-	-	14	85	0.426	-	-	10	50	0.427	0.427	50	08	170	0.292	-	-	13	90	0.381	0.381	90
	16	15	0.271	-	-	11	27	0.450	-	-						10	240	0.300	-	-					
E	06	100	0.292	-	-	06	300	0.461	0.453	412						07	600	0.340	-	-					
	14	20	0.300	0.275	229											12	140	0.351	0.326	1150					
	13	90	0.354	-	-											05	300	0.380	-	-					
	11	45	0.362	-	-											11	90	0.432	0.392	390					
	10	100	0.461	0.401	235																				

NOTE: Depreciation Groups A, B, C, D, & E have been established.

FINANCIAL ANALYSIS SUMMARY

For explanation
see Sec.

		MOBILES/PORTABLES					see Sec.
VALUE	DEPRE- CIATION GROUP	D.O.112 VANCOUVER (\$)	D.O.222 EDMONTON (\$)	D.O.223 CALGARY (\$)	D.O.442 TORONTO (\$)	D.O.552 MONTREAL (\$)	TOTAL (\$)
Net	A	2,688,608	684,400	415,493	8,968,000	779,029	
Present	B	4,116,279	827,956	14,786,967	211,795	2,586,667	
Value	C	2,794,737	6,054,248	985,158	1,301,399	10,803,556	
150-174	D	208,401	10,307,399	154,653	1,441,368	1,770,000	
MHz	E	1,411,296	2,018,109		3,170,637	975,621	
TOTAL		11,219,321	19,892,112	16,342,271	15,093,199	16,914,873	79,461,776
Net	A	23,604	1,331,168	752,034	721,210	952,304	
Present	B	574,561	1,801,343	1,334,204	42,009	3,689,524	
Value	C	3,036,226	484,250	841,808	2,101,226	1,562,683	
450-470	D	889,147	1,012,586	129,847	3,829,050	259,758	
MHz	E	646,928			1,096,415		
TOTAL		5,170,466	4,629,347	3,057,893	7,789,910	6,464,269	27,111,885
							106,573,661
Net Present	A	5,558,754	1,500,438	582,946	16,799,401	3,746,032	
Value in	B	6,633,188	1,507,343	18,587,361	364,133	4,798,156	
1978 \$	C	4,031,016	8,255,057	1,160,859	1,959,113	16,948,822	
150-174	D	258,787	12,799,478	173,168	1,963,002	2,544,577	
MHz	E	1,632,528	2,414,424		4,096,342	1,330,274	
TOTAL		18,104,273	26,476,740	20,504,334	25,181,991	29,367,861	119,635,199
Net Present	A	122,760	262,240	1,157,205	2,293,533	1,710,838	
Value in	B	1,390,874	2,589,636	1,869,275	65,576	5,455,698	
1978 \$	C	4,935,439	649,945	1,093,899	2,992,080	2,080,026	
450-470	D	1,210,931	1,217,352	157,914	4,959,120	323,698	
MHz	E	797,109			1,357,631		
TOTAL		8,457,113	4,719,173	4,278,293	11,667,940	9,570,260	38,692,779
							158,327,978
Salvage	A	104,651	27,885	11,792	322,816	54,839	
Value	B	131,119	29,128	382,263	7,114	92,381	
150-174	C	81,186	167,735	24,090	39,181	336,601	
MHz	D	5,331	263,689	3,618	39,894	51,276	
	E	33,962	50,000		83,910	27,030	
TOTAL		356,249	538,437	421,763	492,915	562,127	2,371,491
Salvage	A	725	33,333	18,284	4,215	24,178	
Value	B	15,654	42,903	31,522	1,026	88,636	
450-470	C	75,000	11,285	19,410	49,897	36,318	
MHz	D	20,818	22,737	2,927	88,190	5,906	
	E	14,651			24,872		
TOTAL		126,845	110,258	72,143	168,200	155,038	632,484
							3,003,975
Replace- ment	A	3,951,628	1,052,923	445,283	12,189,515	2,070,710	
Cost	B	4,951,049	1,099,890	14,434,251	268,618	3,488,305	
150-174	C	3,065,567	6,333,675	909,636	1,479,485	12,710,065	
MHz	D	201,314	9,956,888	136,614	1,506,383	1,936,163	
	E	1,282,415	1,888,000		3,168,443	1,020,650	
TOTAL		13,451,973	20,331,376	15,925,784	18,612,444	21,225,893	89,547,470
Replace- ment	A	27,652	1,272,000	697,701	789,517	922,618	
Cost	B	597,364	1,637,161	1,202,870	39,138	3,382,364	
450-470	C	2,862,000	430,625	740,683	1,904,058	1,385,878	
MHz	D	794,422	867,656	111,710	3,365,337	225,354	
	E	559,077			949,133		
TOTAL		4,840,515	4,207,442	2,752,964	7,047,183	5,916,214	24,764,318
							114,311,788

TABLE 6

FINANCIAL ANALYSIS SUMMARY - LAND STATIONS

VALUE	D.O.112 VANCOUVER ($\$$)	D.O.222 EDMONTON ($\$$)	D.O.223 CALGARY ($\$$)	D.O.442 TORONTO ($\$$)	D.O.552 MONTREAL ($\$$)	TOTAL ($\$$)
Net Present Value 150-174 MHz	2,119,946	3,186,441	2,758,076	2,501,948	2,887,887	13,454,298
Net Present Value 450-470 MHz	918,352	758,116	579,132	1,471,609	1,023,253	4,750,462
					TOTAL	<u>18,204,760</u>
Net Present Value in 1978 \$ 150-174 MHz	2,968,182	3,851,958	3,309,213	3,505,806	4,189,601	17,824,760
Net Present Value in 1978 \$ 450-470 MHz	1,271,885	959,456	765,624	1,903,638	1,326,392	6,226,995
					TOTAL	<u>24,051,755</u>
Salvage Value 150-174 MHz	34,005	42,158	36,125	40,192	48,620	201,100
Salvage Value 450-470 MHz	1,250	9,466	7,549	18,750	13,082	50,102
					TOTAL	<u>251,202</u>
Replacement Cost 150-174 MHz	2,603,452	3,227,630	2,765,755	3,077,095	3,722,319	15,396,251
Replacement Cost 450-470 MHz	1,007,500	762,962	608,451	1,511,250	1,054,783	4,944,946
					TOTAL	<u>20,341,197</u>

TABLE 7

FINANCIAL ANALYSIS SUMMARY410 - 420 MHz BAND

D.O.	MOBILES/PORTABLES			LAND STATIONS		
	<u>Q(78)</u>	<u>SV</u> <u>(\$)</u>	<u>RC</u> <u>(\$)</u>	<u>Q(78)</u>	<u>SV</u> <u>(\$)</u>	<u>RC</u> <u>(\$)</u>
112 VANCOUVER	24	600	22,896	3	75	6,045
222 EDMONTON	430	10,750	410,220	43	1,075	86,645
223 CALGARY	14	350	13,356	2	50	4,030
442 TORONTO	493	12,325	470,322	49	1,225	98,735
552 MONTREAL	1978	49,450	1,887,012	198	4,950	398,970

For explanation, See Sec. 5.5

TABLE 8

COST OF TECHNICAL CHANGES

<u>CHANGE</u>	D.O.112 VANCOUVER (\$)	D.O.222 EDMONTON (\$)	D.O.223 CALGARY (\$)	D.O.442 TORONTO (\$)	D.O.552 MONTREAL (\$)	TOTAL (\$)
CHANGE IN BANDWIDTH	6,085,200	9,358,333	6,784,333	9,272,000	10,046,333	41,546,199
MAJOR FREQUENCY BAND CHANGE	7,099,556	8,191,361	8,982,867	10,064,600	11,236,672	45,575,056
MINOR FREQUENCY BAND CHANGE	4,056,889	4,680,778	5,133,067	5,751,200	6,420,956	26,042,890

TABLE 9
CROSS INDEX FOR WORK STATEMENT

The following is a cross index for the Work Statement (Phase I), included as Appendix A with the Solicitation.

<u>Identification of Tasks.</u>	<u>Report Section(s)</u>
1. Determine the feasibility of utilizing departmental files to establish the equipment elements in Land Mobile Radio systems.	3.2
2. Given the volume of Land Mobile usage, it will be necessary to develop a representative sampling plan to provide an assessment of the frequency dependent component inventory for the bands of 410-420 MHz, 450-470 MHz, and 150-174 MHz.	4.0
3. Because the equipment varies from many years old to new, determine the distribution of ages of equipment, both for current inventory and for the spare parts inventory.	4.0
4. Assess the accuracies and quality of the data utilized to create the equipment model.	4.0
5. For the relevant equipment configurations, collect data on the initial costs, replacement costs and salvage value.	covered, but removed for publication
6. Utilizing the cost and age data, calculate the present value of the systems.	5.0
7. Combine the information gathered to present, in user approved formats, an economic estimate with an estimate of accuracy of the costs incurred by users to modify or replace components if required to change frequencies or comply with higher equipment standards.	6.0

Identification of TasksReport Section(s)

- | | | |
|----|--|-------------------------------|
| 8. | Indicate the weaknesses in current data sources and recommend methods by which the DOC may upgrade its data bases to provide more accurate estimates in the future. | 3.0
+7.0 |
| 9. | Provide the DOC with cost estimates to analyse the data for a nationwide assessment of the frequency dependent component inventory for Land Mobile bands. These estimates shall be made available by band. | covered in
separate letter |

TABLE 10

1978 YEAREND LICENCED LAND MOBILE QUANTITIES

DISTRICT OFFICE	BAND					
	150 - 174 MHz		410 - 420 MHz		450 - 470 MHz	
	Mobiles/ Portables.	Land Stations.	Mobiles/ Portables.	Land Stations.	Mobiles/ Portables.	Land Stations.
Vancouver (112)	14,263	1,426	24	3	3,969	397
Edmonton (222)	22,955	2,296	430	43	4,690	469
Calgary (223)	17,093	1,709	14	2	3,246	325
Toronto (442)	19,603	1,960	493	49	7,720	772
Montreal (552)	21,971	2,197	1,978	198	6,190	619

APPENDIX I
WORK STATEMENT



Appendix ATerms of ReferenceLAND MOBILE INVENTORY STUDYWORK STATEMENTINTRODUCTION

The Department of Communications (DOC) was formed by Act of Parliament in 1969 and given the responsibility for the management of the radio spectrum. This includes responsibility for allocation, assignment, and efficient use of the spectrum.

As part of its mandate to administer the spectrum in the public interest, the Department of Communications, through its Policy and Regulatory branches, is considering a variety of possible changes or reallocations which may serve to improve assignment efficiency in general.

⇒ Reasons for these changes might involve:

- (a) reallocation of a portion of a band from one service whose needs do not warrant the whole band to another service whose growth requires an expanded or new allocation, i.e. from broadcasting to land mobile.
- (b) within a service, re-assignment of users from one portion of a band to another area allocated to the service in order to allow a new, more spectrum-efficient usage to be implemented, i.e. clearing a portion of the 15MHz land-mobile band of its existing FM users to make room for improved technologies.
- (c) to allow for new higher specifications of equipment, making users more spectrum-efficient and thereby allowing more intensive use of the same piece of spectrum.

A major constraint in changing policies is the user and manufacturer investment in radio equipment and the department's desire to avoid disruptive reallocations which would unreasonable reduce the value and useful life of equipment. It is in this context that this study is proposed.

OBJECTIVES

The objectives of this study will be:

- 1) to test a method of assessing the economic impact of spectrum policy changes on the land mobile radio equipment inventory in Canada, and to test this method for one or more given problems with particular emphasis on quality of results and accessibility and quality of the needed data.
- 2) to create a data base to be used in such impact assessment (assuming the achievement of objective #1) which will allow estimates to be made of inventory value in various frequency bands and geographic areas and which will include information on equipment age and cost structures.

This will provide the department with an analysis tool indicating the equipment investment and costs implied in departmental changes in the land mobile communications segment.

STRUCTURE OF THE STUDY

The study will be conducted in two phases. The first phase will be largely exploratory in nature and be a pilot study in Toronto, Montreal, and Vancouver. Departmental studies have indicated possible land mobile spectrum allocation shortages will first occur in the major urban centres. The DOC study "Assessment of Existing Use of Land Mobile Allocations" concluded that:



Appendix ASTRUCTURE OF THE STUDY

"Toronto has virtually no clear channels for future use and expansion of land mobile allocations. Montreal, Edmonton, and Vancouver, while they do have existing capacity in the present land mobile allocations, will require additional allocations prior to the year 2000 to accommodate even conventional land mobile growth."

In addition to the fact that these three centres have the most serious spectrum shortages, they were also selected to represent the different regional data bases, geographical terrains, industrial segmentation, and allocation procedures.

Phase I will analyse the inventory in the 410-420 MHz, 450-470 MHz, and 150-174 MHz bands. (Land mobile usage also occurs in the 27-50 MHz and 138-150 MHz bands.) According to departmental statistics, there are approximately 18,600 base stations in these three metro areas in all land mobile bands. The 150-174 MHz, 410-420 MHz, and 450-470 MHz bands account for 75 percent of this volume, i.e. 14,000 base stations. Assuming that the average cost of a land mobile system is \$10,000, there is an equipment investment of \$140 million. Thus, it is important that DOC has a good information base of the existing types of equipment used, their age distribution and cost structure to assess the impact of changing frequency allocations or radio specifications. It is estimated that several thousand users might be affected by such changes and user costs running into millions of dollars might be incurred.

Much of the equipment data required is available "in-house" in district office files in either computer readable form or paper form. However, each region maintains its own computer files and records. Thus, the amount of detail of information, the proportion computerized, its accessibility and quality will likely vary by region. It is unlikely that the data will be in the exact form required to develop an equipment model.

National Telecommunications Branch (DGTN) and Technology and Systems Research and Development (DGTS) staff will lay the groundwork in appropriate regional offices for the contractor. The support and time of regional and district office staff will be assured to provide assistance in obtaining access to the files and to discuss typical or representative system types, as well as unique features in each geographical area.

Because of the magnitude of the mobile radio inventory, statistical sampling will be necessary. The contractor will interact with the policy analysts in the Department to discuss their information needs and the different reporting formats required in deriving an appropriate segmentation for the sample.

Information on the age distribution of the equipment may be difficult to obtain. Some indication can be gleaned from the date of issue of the licence. However, there is a margin of error due to second-hand equipment and trades. Departmental files may not be up-to-date in terms of the types of equipment currently in use because the on-site inspection budget is small and the Radio Act (Regulations) permits the change of equipment within certain parameters without reference to the Department. Perhaps the manufacturers, utilizing model numbers, will have a feel for the age of equipment. The age distribution of equipment is important in establishing reasonable amortization periods if changes are implemented.

Manufacturers will need to be interviewed to obtain costing data-- both initial costs, possible salvage value, and replacement costs.

The next major task of the contractor will be to establish the feasibility of providing the necessary data, utilizing departmental files and interviews with manufacturers, to the policy makers. Where are the main weaknesses in the process? How accessible and valid are available information in the consultant's opinion?



Appendix ASTRUCTURE OF THE WORK

An inter-branch working group has been formed to monitor and direct this contract. Once the acceptability and quality of the needed data has been established and discussed with the Department's working group, the consultant will then create an equipment model to estimate the value of the frequency dependent components of the inventory of land mobile radio users. A frequency dependent component is one which has to be modified or replaced as a result of a change in assigned frequency either within bands, between bands, or to new bands or higher equipment standards. In other words, cost estimates should be available for various components of the system as well as for the total system.

IDENTIFICATION OF TASKSPHASE I

1. Determine the feasibility of utilizing departmental files to establish the equipment elements in land mobile radio systems.
2. Given the volume of land mobile usage, it will be necessary to develop a representative sampling plan to provide an assessment of the frequency dependent component inventory for the bands of 410-420 MHz, 450-470 MHz, and 150-174 MHz.
3. Because the equipment varies from many years old to new, determine the distribution of ages of equipment, both for current inventory and for the spare parts inventory.
4. Assess the accuracies and quality of the data utilized to create the equipment model.
5. For the relevant equipment configurations, collect data on the initial costs, replacement costs and salvage value.
6. Utilizing the cost and age data, calculate the present value of the systems.

Data for these tasks may be obtained from DOC/HQ, Regional or District Office files and supplemented by interviews with manufacturers, other non-users contacts, or by other means except contact with user groups.
7. Combine the information gathered to present, in user approved formats, an economic estimate with an estimate of accuracy of the costs incurred by users to modify or replace components if required to change frequencies or comply with higher equipment standards.
8. Indicate the weaknesses in current data sources and recommend methods by which the DOC may upgrade its data bases to provide more accurate estimates in the future.
9. Provide the DOC with cost estimates to analyse the data for a nationwide assessment of the frequency dependent component inventory for land mobile bands. These estimates shall be made available by band.

IDENTIFICATION OF MILESTONES FOR PHASE I

1. Production of working group reports for the inter-branch working group upon completion of tasks 1 and 2 and upon completion of tasks 3 and 4.
2. Production of final reports for each of tasks 7, 8, and 9.



APPENDIX II
COMPANY CODE DATA

(This Appendix not included in general distribution)



APPENDIX III
AGE DISTRIBUTION DATA

(This appendix not included in general distribution)



APPENDIX IV
LETTER TO MANUFACTURERS



THE FOLLOWING QUESTIONS PERTAIN TO SEPARATE FREQUENCY BANDS AND TO THE
EXTENT POSSIBLE, ANSWERS SHOULD BE FOR EACH BAND

- 138 to 150 MHz
- 150 to 174 MHz
- 410 to 420 MHz
- 450 to 470 MHz

1. What have been the annual quantities of mobile equipment sold to the Canadian market, 1962 to present, under the following breakdown?
 - base stations or repeaters
 - mobiles (vehicular)
 - portables
 - paging
 - other
2. What has been the sales breakdown, expressed as a percentage of total, sold to the Canadian market, 1962 to present, for example?
 - government (federal, provincial, municipal)
 - utility
 - communications
 - rail transport
 - petroleum
 - other major markets
3. What percentage of sales represents used or reconditioned equipment, 1962 to present?
4. What represents the average number of frequencies per unit for base stations, mobiles, portables and what has been the average selling price for each, annually since 1962?
5. What is the estimated salvage value of the average base station, mobile and portable for the following approximate vintages?
 - 1975 to present
 - 1970 to 1975
 - 1965 to 1970
 - 1960 to 1965
6. For the above vintages, what would be the approximate cost per frequency pair (labour plus parts) to change frequency bands as follows?
 - 138 to 150 MHz band to 150 to 174 MHz band
 - 138 to 174 MHz band to 410 to 420 MHz, 450 to 470 MHz bands
 - frequency change in any band of ± 5 MHz
7. For the vintages of Item 5, what would be the approximate cost per frequency pair, (labour plus parts) to convert from 30 KHz to 15 KHz spacing in the high VHF band, and from 25 KHz to 12.5 KHz spacing in the UHF bands?.

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