BENEFIT-COST ANALYSIS OF THE VANCOUVER POLICE DEPARTMENT'S MOBILE RADIO DATA SYSTEM

James McDavid
James J. McRae

Centre for Public Sector Studies
School of Public Administration
University of Victoria

FINAL REPORT

CENTRE FOR PUBLIC SECTOR STUDIES

SCHOOL OF PUBLIC ADMINISTRATION

UNIVERSITY OF VICTORIA

BENEFIT-COST ANALYSIS OF THE VANCOUVER POLICE DEPARTMENT'S MOBILE RADIO DATA SYSTEM

James McDavid
James J. McRae

Centre for Public Sector Studies
School of Public Administration
University of Victoria

FINAL REPORT

April, 1985

DOC CONTRACTOR REPORT DOC-CR-TS- 046/85

DEPARTMENT OF COMMUNICATIONS - OTTAWA - CANADA

RADIO SYSTEMS R&D

TITLE: BENEFIT-COST ANALYSIS OF THE VANCOUVER POLICE DEPARTMENT'S MOBILE RADIO DATA SYSTEM

AUTHOR(S): MCRAE JAMES J., MCDAIVD JAMES

CONTRACTOR: UNIVERSITY OF VICTORIA
P.O. Box 1700
Victoria, British Columbia
V8W 2Y2

DEPARTMENT OF SUPPLY AND SERVICES CONTRACT NO: OST84-00318

DOC REQUISITION NO: 36100-4-4139

DOC SCIENTIFIC AUTHORITY: R.J. MORLEY
RADIO SYSTEMS R&D

CLASSIFICATION: UNCLASSIFIED

DATE: AUGUST, 1985

ACKNOWLEDGEMENTS

This Report is sponsored by the Communications Research Centre of the Department of Communications (DOC, Ottawa). Throughout the process, Mr. R.J. Morley and Ms. Bev Hillman of DOC provided the authors with helpful suggestions and background publications. In addition, members of the Vancouver Police Department have demonstrated total co-operation with this research effort. We would especially like to thank Superintendent K.R. Cocke, S/Sgt. Larry Richardson, S/Sgt. John Unger and all patrolmen who filled out our questionnaires, for their assistance during the period of benefit data collection. Also, many of our technical questions on this phase of the research were answered by P. Joan Furnival of the Court Services Branch, Ministry of the Attorney General, Province of B.C., and June J. Bitzkal, Bylaw Fines Collection Office, City of Vancouver.

During the period of time when the cost data were being assembled, we were greatly assisted by Mr. Paul Vanderwood and Mr. John Hall of the City of Vancouver.

In Victoria, Mr. Robert Lee capably developed the required software and ran the calculations to our specifications. Finally, Heather Bryan and Deborah Needley worked overtime at great speed and efficiency to type this Report.

Needless-to-say, any errors in the analysis or mistakes of interpretation are the responsibility of the authors alone.

EXECUTIVE SUMMARY

The primary purpose of this Report is to formally evaluate the Vancouver Police Department's Mobile Radio Data (MRD) System using benefit-cost methodology. The MRD System is capable of performing two basic functions. First, the technology gives officers the ability to access remote law enforcement data files without relay through dispatch personnel. Also, the system provides a non-verbal means of transmitting messages - dispatch, tactical, status and descriptive - between the police communications centre and patrol units operating in the field. For a variety of reasons, the remote data base access function is the dominant feature of the system as used by the Vancouver Police Department. Thus, evalution is based solely on this output.

The ultimate purpose of MRD technology is to assist patrol officers in producing swifter and more certain arrests. In order to calibrate the effect of the MRD System on the rate and number of arrests, officers making warrant arrests were asked to fill out a simple questionnaire. The survey form was designed so that the arresting officer could indicate the type of arrest made - criminal, traffic bench, bylaw or failure-to-appear - the charge involved if the arrest was for a criminal event; whether his patrol vehicle was equipped with an MRD unit; whether the MRD unit had been used in connection with the arrest; and, if the unit had been used, whether or not he would attribute the arrest to his use of the MRD unit.

The survey instrument was in place between January 1, 1985 and March 20, 1985. during this period, a total sample of 1428 arrests was produced. With respect to traffic bench warrant arrests, the MRD System was available in 59.5% of the sampled arrests, and deemed to have been responsible for 83.5% of these arrests. For bylaw arrests, the system was available in 61.4% of the sampled arrests, and responsible for 88.2% of those cases. Data on criminal arrests is broken down into drug offenses, other crimes, property crime and violent crime in the body of the Report. In aggregate, the MRD System was available in 36.5% of the criminal arrests, and deemed to be responsible for 39.9% of the arrests made when the MRD System was available.

These benefits were converted into dollar figures whenever hard information was available on the value of the benefit being produced. For example, traffic bench and bylaw arrests generate a tangible financial benefit in terms of recovered traffic fines. A range of $25 to $30 per ticket was used to perform tests to determine how sensitive the benefit-cost ratio is to these lower and upper bounds. No attempt was made to place a value on criminal or failure-to-appear arrests, nor was any value placed on non

tangible benefits such as the increased sense of officer safety. Thus, the benefit measures used in the analysis are only the quantifiable fraction of benefits available from the system.

The second major quantifiable benefit is salary savings from not having to hire dispatchers to handle the volume of MRD database requests. These have been estimated at $99,000 per year in 1980, but the volume of requests being processed by the MRD System in later years would require personnel expenditure well in excess of $99,000 if accomodated by voice channels. Thus, benefit estimates from this source are also stated conservatively.

System costs in terms of hardware, software, staff training and maintenance are estimated to be $688,660 in 1980. Software development charges for digital transmission, and some hardware subsidies paid by the federal government have not been factored into the analysis. Annual system maintenance costs have been discounted back to 1980.

The combined benefit and cost information is arrayed in several different ways, using discount rates of 5%, 10% and 15%, and ticket prices of $25 and $30 per ticket. Benefit-cost ratios range from 1.054 in the worst case to 1.508 in the best case. Payback periods range from a high of 10 years for the worst case to 6 years for the best. The internal rate of return is calculated at 19.91% for the best case, and 16.57% for the worst. From this information, and from the fact that benefits have been consistently underestimated, it is concluded that the MRD System is a productive social investment.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Purpose of the Study

Stimulated in large measure by grants made available in the U.S. under the Law Enforcement Assistance Administration (LEAA), a number of digital communications systems were implemented during the 1970s by various U.S. police forces. Unfortunately, the early enthusiasm for digital communications was dampened by problems with host computers, and terminals which were cumbersome and unreliable. Recently, however, third generation micro-process-based mobile digital terminals have been able to solve most of the problems which plagued the earlier versions, and rekindle the enthusiasm for the concept.

In Canada, the Vancouver Police Department (VPD) is at the forefront with respect to the application of this technology to the area of criminal justice enforcement. After an early false start with a system which proved faulty, and a trial period with a new improved system, the VPD introduced their Mobile Radio Data (MRD) System on July 12, 1980. It is the primary purpose of this Report to formally evaluate the MRD System using benefit-cost methodology. A secondary purpose of the research is a preliminary investigation of the feasibility of using mixed digital and voice communications systems in other applications. Observations relevant to this secondary objective will be presented in Chapter 6.

While the authors have made every attempt to ensure that only factual material is included in the calculation of benefit and cost measures, readers must be warned that exact scientific precision is not possible in studies of this sort. The main problem is on the benefit side of the equation. The ultimate, long term objective of the MRD System, and in fact of all police activities, is to produce swifter and more certain apprehension rates. It is anticipated that by raising the costs of criminal activity in comparison to legal activity by swifter and more certain arrests, it is possible to change aggregate behaviour towards more legal and less criminal activity. Measurement of the degree to which the MRD System contributes to this ultimate, long term objective is very difficult. This difficulty of measurement arises due to the existence of a multitude of alternative economic, political and behavioural factors which can also influence the level of criminal activity. Where possible, and given the availability of the required data, the long term program objective of reduced criminal activity has been "unbundled" into its constituent shorter term objectives. However, it must be remembered that the calculation of proxy measures for many of the benefits which make up the heterogeneous output of "criminal activity" may not be measured with the same degree of accuracy as the variables used in scientific and engineering research.

Finally, one important issue is mentioned briefly in the Report, but receives no further analysis, because it is outside of the scope of any measured benefit or cost. However, due to the

fundamental, long term importance attached to the concept of privacy of information, it is important that the topic be mentioned at this early point in the Report. Digital communications technologies provide officers with the ability to engage in mass data checks at practicaly zero variable cost once the system is operational. Previously, frequency congestion costs and peer group pressure effectively meant that each data request had an implicit cost, and officers responded optimally by reducing their demand for data base information. This move from the selective use of data base inquiries to the possibility of mass data checks has obvious implications with respect to the concept of citizen privacy. The issues raised with respect to the accessibility of information on citizens is broader than just the topic of law enforcement data bases, but any discussion of social benefits and costs framed in benefit-cost terms must recognize that additional, non-quantifiable variables have a role to play in ultimate decision making.

1.2 Police Command and Control Systems

Recent rapid growth in computer-assisted communications technologies, combined with the desire to improve police effectiveness in large urban centres, have jointly resulted in the growing use of MRD Systems. The performance features of this augmented communications capability will be further discussed in Section 1.2.1, but it is important at this point to note that the MRD technology is, in fact, one of a series of closely related

technologies in the general area of Police Command and Control (PCC) systems. The PCC technologies, sometimes expanded to include communications issues, such as radio signal reception and distortion, speech scrambling, radio spectrum allocation, etc., is a generic term used to describe four nested communications technologies: MRD, Computer-Aided Dispatch (CAD), Nine-One-One (911) common emergency number, and Automatic Vehicle Monitoring (AVM).

For evaluation purposes, each of these elements can in principle be considered as a separate entity, but because the Vancouver Police Department (VPD) implemented both the MRD and 911 technologies simultaneously, and has not yet implemented a CAD technology, it is imperative for the selection of output measures to understand the points at which one technology intersects with another.

1.2.1 Mobile Radio Data (MRD)

The MRD System is capable of performing two basic functions. First, it can provide a non-verbal means of transmitting messages (dispatch, tactical, status, and descriptive) between the police communications centre and patrol units, or for descriptive messages only, between patrol units themselves. In addition, the technology is particularly well suited as a means by which officers can directly access remote

law enforcement data files without relay through dispatch personnel. Patrol units equipped with MRD terminals are able to access the Canadian Police Information Centre (CPIC) data base for information on stolen vehicles, property and boats, and the names of wanted persons, probationers and parolees. Also, driver's licence and motor vehicle licence plate data can also be accessed directly by the patrol units.

1.2.2 Computer-Aided Dispatch (CAD)

Sohn et. al. (1975, p. 13) provides a detailed discussion of the various possible features which collectively constitute a CAD system for police purposes. However, the best working definition of the CAD technology is provided by Colton, Brandeau and Tien (1983, p. 21).

> "CAD systems are those systems which involve the computer in the process of handling service calls from the public, in making decisions as to which patrol units should be dispatched to an incident, and in making appropriate adjustments in the status of units as necessary. In general, CAD systems do not completely automate the normal handling of service calls from the public, but instead make use of the computer's unique capabilities to enhance the handling of calls for service.
>
> CAD generally assists the complaint operator by verifying incident-related information to the extent possible (most commonly by verifying addresses) and checking to see if certain necessary information (such as incident address and incident type) has been entered. Most CAD systems also automatically determine the beat in which an incident is located (by checking a geocoded address file) and generally assign a case number and priority to each call. If the address has a "dangerous" history (which the computer would check by searching past incident files), the computer may also report this. The incident-related

information is then routed automatically to the appropriate dispatcher.

Based on the status and anticipated locations of the patrol units (which the CAD system checks from a field unit status file and a personnel file), the computer typically recommends to the dispatcher several possible units to dispatch. Once a unit has been dispatched, the computer can automatically record the time it is dispatched, the time it arrives at the scene, and the time it becomes free. CAD also assists the dispatcher by keeping track of the status of all incidents, and provides the dispatcher with instant recall of dispatch data."

As a final point, it is instructive to note that for police departments in the United States, the trend has been to install CAD before any other PCC technologies. Based on their survey results, Colton, Brandeau and Tien (1983, p. 40) report that there are only 30 operational MRD Systems and 65 operational CAD systems. Also, seventy-five percent of the cities applying for new MRD systems already have a CAD technology in place. It is generally agreed in the literature on this topic that CAD is at the heart of the PCC technologies in that it provides police departments with their first exposure to an automated police information system. The fact that the VPD did not implement a CAD system prior to introducing the MRD System is based on the subsidy support available for purchase and installation of the MRD System, and does not, in any fashion, affect the benefit-cost analysis of this technology.

1.2.3 Nine-One-One (911)

The basic 911 system provides a central answering point to which all police, fire, ambulance and poison control centre calls are routed. As emergency calls arrive, they are distributed to the next free operator on an equal load basis. In the VPD system, calls requiring police attendance are dealt with directly by the operator, while requests for the other emergency services are transferred immediately to the proper agency.

1.2.4 Automatic Vehicle Monitoring (AVM)

This technology is generally linked to an operational CAD system to produce a more complete computerized dispatch operation. An AVM system allows the police dispatcher to have exact locational information on each patrol unit, and in addition, can provide additional status data such as "in pursuit", "en route to scene", etc.

1.3 Previous Work

1.3.1 U.S. Studies

Despite its obvious importance as a crime prevention tool, MRD technology has received surprisingly little formal

evaluation in the United States. Both Sohn et al. (1975) and Urban Sciences (1973) provide general discussions of the MRD technology and its potential contribution to law enforcement, but no actual evaluation results are presented. More formal studies of three MRD test systems have been done in the United States for the Oakland Police Department, the Hennepin County Sheriff's Department, and the Minneapolis Police Department. All studies were done in 1975, but none employed formal benefit-cost methodology. The major conclusions of these studies are discussed in Colton, Brandau and Tien (1983, p. 40-49).

With respect to officer effectiveness measures, only the Oakland Police Department study provides statistical performance indicators. Units equipped with mobile digital terminals (MDT's) generated 2.8 times as many warrant-related arrests and vehicle recoveries in comparison to non-MDT equipped units. As an indication of the almost unlimited ability of the MRD technology to produce mass data checks, the Oakland study reports that to generate this 2.8 increase in arrests and vehicle recoveries, MDT patrol units had a 14.5 fold increase in requests.[1]

From this, it can be ascertained that when the costs of information in terms of officer waiting time and dispatcher resistance are reduced to near zero (MRD technology), officers significantly increase the amount of desired information. In other words, when equipped with MRD technology, officers request information on suspects and vehicles which have a lower probability of ultimately resulting in an arrest or recovery.

Without the MRD technology, officers voluntarily reduce their demand for information, and seek hard data only on the situations most likely to produce ultimate results.

This move from a more selective use of data base checks, to mass data searches which can be done at nealy zero cost once the MRD system is operational, is shown in the Oakland study to produce an increase in officer effectiveness, i.e. the 2.8 increase in warrant-related arrests and vehicle recoveries.

Regarding the objective of reduced voice congestion, the limited information which exists from previous studies supports the contention that MRD technology does not reduce radio air time. This follows because of the large increase in the number of data base requests, and voice communications which previously could not obtain air time. If it can be ascertained that the increase in voice communications is crucial to support the level of police work, it may be stated that MRD technology contributes positively to the slightly modified objective of increased communications capability. This matter will be dealth with in more detail later in this Report.

In summary, the few MRD evaluations which have been performed on U.S. systems provide only a limited amount of hard information. Except for some information onthe outputs of increased officer effectiveness and reduced voice congestion, the contribution which the MRD technoloby makes to achieving other system outputs has not been rigorously investigated in the United States.

1.3.2 Canadian Studies

Since its introduction in 1981, the VPD's MRD technology, has been the subject of three separate investigations. The first, entitled Traffic and Spectrum Use Study of Vancouver Police Department Mobile Radio Data System (Cantel, 1982) is statistical analysis of police communication tapes, produced during busy hours, before and after the introduction of the MRDS. The second study is authored by T.S. Palys et al. (1983), and is titled A Behavioural Evaluation of the Vancouver Police Department's Mobile Data System. McRae (1984) provides a preliminary investigation of how benefit-cost methodology can be applied to evaluate the usefulness of the technology.

The Cantel (1982) study has two basic purposes. The first is to compare police communications with respect to message content, radio channel utilization and traffic volumes before and after introduction of the MRD System, but during the police busy hours. The second output is to assess the impact of the digital technology on radio spectrum utilization, and growth of data requests to the (remote) CPIC.

To provide answers to these questions, the authors studied voice and MRD transmissions which are stored on magnetic tape by the VPD. Data were obtained for the pre-MRD situation by listening to 34 hours of voice communications generated during the third quarter of 1980. Post MRD data, consisting of 42 hours

of voice and 21 hours of digital communications, were obtained for the first quarter of 1982.

Three relevant conclusions emerge from the Cantel (1982) study. First, it is shown that the addition of MRD technology to the existing voice communications system resulted in very little change in the average message length and volume distribution of different message types on the voice radio channels. This conclusion of a basically unchanged structure of voice communications remained valid when measured in terms of both the number of messages, and the total amount of voice air-time.

In aggregate, there was a small (6.6%) increase in the total number of voice messages after the introduction of digital capability into the communications system. This observation differs only in magnitude from the U.S. results reviewed in Section 1.3.1. There it was found that the number of voice messages previously being "squeezed out" due to radio band congestion expanded significantly to immediately fill the space being created by the introduction of digital capabilities. In the case of the VPD, the available evidence supports the conclusion that there has been no reduction in the net amount of voice air time. Introduction of MRD technology has, however, produced a weaker version of the result discovered in the U.S. studies. That is the fact that the addition of digital transmission capability has allowed 6% more voice communications to obtain air time. There is, however, no way of knowing the "value" of these increased transmissions. Work on this topic

must assume that the increase the number of voice messages are valued at the same rate as the voice transmissions which could obtain air time in the pre-MRD situation. In other words, it must be assumed that the increase in voice communications is crucial to support the existing level of police work, and that the marginal benefit equals the average benefit of this performance indicator.

The third issue is the observation that the overlay of MRD technology on the previously existing voice-only system resulted in a nearly 100% increase in the number of data base enquiries. For the purposes of this Report, one enquiry is deemed to be the original query plus the associated response. If this increase in data traffic were to be carried by a conventional voice channel, it would occupy the equivalent of two voice channels. Thus, it may be concluded that the addition of the single data channel to support the MRD technology carries the same message content as two conventional voice channels.

The Palys et al. (1983) report is a behavioural study concerned with how the officers in the field are actually using the MRD System. The research methodology employed in this report is to interview officers, dispatchers and police administrators with respect to their expectations and opinions regarding the technology. Also, the research group placed observers in the police cars to record, for various police activites, whether the officers demonstrated a preference for communications by voice or by using the digital system. In total, 2015 transmissions

ranging from sign-on, narrative, and status messages, to drivers license, vehicle plate, wanted person, stolen property and vehicle registration checks were observed. The researchers then recorded whether voice or digital communication was the chosen method of communication. The results produced by this observed data are strongly supportive of the third conclusion reached in the Cantel (1982) study, regarding the importance of digital transmission for data base enquiries.

In addition and based on the subjective opinion of the in-car observer, the authors attempted to estimate whether or not the MRDS system contributed significantly to an arrest. During the period of observation, the research team observed 14 arrests, and concluded that 9 of the 14 were made possible by the existence of the MRD System. See Palys (1983, p. 67). Other results generated in this study will be discussed in the appropriate sections of this Report.

The McRae (1984) study was a preliminary investigation of the possibility of using benefit-cost methodology. This Report is a continuation of McRae's earlier work.

1.4 Organization of This Report

The next chapter gives a brief discussion of some of the more important issues relevant to the application of benefit-cost methodology to the MRD technology. In general, specific methodological points are discussed as they occur, but this chapter gives a brief introduction to some of the most important general points.

Chapter 3 presents the measures used to calibrate the increase in officer effectiveness due to the implementation of the MRD System. The MRD System has the capability of generating two separate outputs - automated data base access and non-verbal transmissions - but only the data base access features have been utilized by the VPD. Both the Cantel (1982) and Palys (1983) studies report that officers ony rarely use the ability to report status change messages by means of the MRD System.[2] Thus, increases in officer effectiveness are measured solely with respect to the output of automated data base access.

Chapter 4 continues the line of argument developed in the preceding chapter by estimating monetary benefits due to the introduction of the MRD System. Several assumptions must be introduced in order to quantify the value of the benefits being generated, and these are identified and discussed in the chapter.

System costs in terms of hardware acquisition, software production, installation and the opportunity costs of staff training are discussed in Chapter 5. Some difficulties in developing these cost figures were experienced due to different phases required to introduce the system, but the final cost figure used in the benefit-cost calculations appears to be accurate.

Chapter 6 presents the results of the exercise in terms of the various different ways in which the data on benefits and costs can be arrayed. Sensitivity tests using different discount rates are performed and presented.

Footnotes are to be found at the end of each chapter.

FOOTNOTES

1. The Study Group Report (1974, p. 13) mentions that the City of Palm Beach experienced a 14-fold increase in the number of inquiries after patrol units were equipped with digital terminals.

2. Officers apparently find it more efficient to report status change messages by means of voice channels because of the collective security generated in knowing where the other units are located. In technical terms, voice communication for status messages between any patrol unit and the police communications centre produces a "public good" for all other patrol units in the same policing district. A second reason for the use of voice over digital communication for status messages is simply that officers find it physically more convenient to report status changes while driving.

CHAPTER 2

THE APPLICATION OF BENEFIT-COST METHODOLOGY TO THE MRD TECHNOLOGY

2.1 Introduction

While it is not the purpose of this Report to provide a rigorous discussion of benefit-cost methodology beyond that applicable to the MRD technology, a particularly good general summary is contained in the publication by the Treasury Board Secretariat (1976, p. 3).

> "Benefit-cost analysis is a method of evaluating the relative merits of alternative public investment projects in order to achieve efficient allocation of resources. It is a way of identifying, portraying and assessing the factors which need to be considered in making rational economic choices. It is not a new or mysterious technique. In principle, it entails little more than adjusting conventional business profit-and-loss calculations to reflect social instead of private objectives, criteria, and to reflect social instead of private objectives, criteria, and constraints in evaluating investment projects. (This is not to say, of course, that this change in point of view is altogether easy to carry out.)"

The essential point is that projects, or investments, yield a stream of benefits and costs that stretch out over a period of time. To get a single measure of the net benefit of a project, the researcher must aggregate the stream of benefits and costs over time.

When this methodology is applied to the issue of investment in MRD technology, it is important to remain modest with respect to

what can ultimately be accomplished. As discussed in Chapter 1, the long term objective of the MRD technology is to produce improved apprehension rates. It is anticipated that the possibility of swifter and more certain arrest effectively raises the cost of criminal activity at the margin. This increased cost of illegal versus legal activity, it is hoped, will ultimately be noticed by the population, causing a general shift in behaviour towards legal activities.

However, when attention turns from theoretical modelling to measurement, it becomes obvious that it is extremely difficult to measure the influence of variables which operate deep within a complex social structure such as Canada's. In order to make the problem tractable, it is necessary to reduce the scope of the benefit-cost analysis. Specifically, the long term objective of reduced criminal activity must be disaggregated into shorter run objectives which are potentially quantifiable, such as arrests, stolen vehicles recovered, etc.

This disaggregation of benefit measures to be used in the analysis becomes even more important when it is noted that crime is a very heterogeneous phenomenon. Only by measuring with respect to a number of shorter run benefits is it possible to capture enough elements of this basic heterogeneity to make the analysis worthwhile. Methodological issues of this sort, and a justification of the various shorter term benefits used in the analysis, will be given in the next two chapters. This chapter

will present a very brief discussion of various criteria which may be used to determine the economic viability of a project.

2.2 Present Value Calculation

The value today of a dollar received in future years is the present value of the dollar. Thus, when the stream of project benefits (B_t)and costs (C_t) extend into future years, the two can be compared only in terms of the common measuring rod of present value. For a project which is expected to last for T years, the present value (V) is determined by the relationship

$$1) \qquad V = \sum_{t=0}^{T} \frac{B_t - C_t}{(1 + r)^t}$$

where r is the appropriate discount rate at which future benefits and costs are "brought back" to the present period.

Many complications in terms of project size, and the start-up time of the project can be introduced, but essentially if V is negative, the project should not proceed, and if V is positive, it should.

2.3 Internal Rate of Return

A second criterion which may be used to determine the economic viability of a project is the internal rate of return (IRR). This is the discount rate (r) in equation 1 which just makes the present value of the project equal to zero. Thus, it is defined as equation 2 below.

$$2) \qquad 0 = \sum_{t=0}^{T} \frac{B_t - C_t}{(1 + r)^t}$$

If the calculated IRR exceeds r, the project has a positive present value and hence, should proceed. Alternatively, if IRR is less than r, the project should be rejected, as the funds required have a higher value somewhere else in the organization.

Again, there are many complications when projects of differing scales are considered. Also, since the required equation is T^{th} degree polynomial, the IRR may not be unique. However, for the case of a single project, this method shows the internal value of the funds when dedicated to the project in question.

2.4 The Benefit-Cost Ratio

A third criterion to aid decision making regarding project profitability is the benefit-cost ratio shown by equation 3.

$$3) \qquad \frac{B}{C} = \frac{\sum_{t=0}^{T} B_t/(1+r)^t}{\sum_{t=0}^{T} C_t/(1+r)^t}$$

The ratio is simply the discounted stream of benefits to year T, divided by the discounted stream of costs over the same period. It is obvious that a benefit to cost ratio which is greater than unity implies that the project should proceed. Thus, the present value calculation shows the difference, in terms of present value, between benefits and costs, while the benefit-cost number shows their ratio.

2.5 Evaluating Inputs and Outputs

For the case of the MRD System, evaluation at market prices for the required inputs is relatively straightforward. Most of the required hardware and software inputs have been priced by a competitive market structure. Thus, it can be safely assumed that prices reflect marginal social costs. Shadow prices were required

only for the period of time when VPD staff were involved in the trial and demonstration period of the system. This issue is further discussed in Chapter 5.

With respect to evaluation of outputs, Section 2.1 of this chapter has introduced some of the difficult conceptual problems involved. Detailed discussion of these issues will be given in the next two chapters.

2.6 Evaluation of Intangibles

It is a very difficult task to assign a monetary value to outputs such as the increased sense of safety experienced by officers, or the saving of time due to a MRD check. When intangibles are generated, money values may sometimes be inferred from some other source of market data, say insurance policy rates. Another approach is to leave the intangible benefit out of the calculation, then infer what monetary value would have to be assigned to the intangible benefit in order to produce a benefit-cost ratio which exceeds unity. Obviously, if the benefit-cost ratio already exceeds unity without assigning a value to the intangible benefit, then there is no need to proceed any further.

One of the most important intangible outputs of the MRD System is the reduction in the risk of death or injury experienced by patrol officers. This issue will be discussed in more detail in the next two chapters, but at present one important point needs to

be noted. If a single patrol officer, or any other individual for that matter, were asked how much money he would be willing to accept to offset the risk of exposing himself to possible death or injury, the answer would be very large. Projects cannot be evaluated by designating in advance those persons whose lives will possibly be lost. The best that can be done is to assign subjective probabilities to individuals in the group being exposed to more or less risk. However, even this can be a very difficult analytical task, so that it is often preferable to leave the evaluation of risk entirely out of the calculation. So long as the benefit-cost ratio exceeds unity, a single project can be justified on the basis of tangible benefits alone.

2.7 The Social Discount Rate

There exists a large literature on whether or not the observed market rate of interest is a robust estimator of the social rate of discount. It will serve no useful purpose in this Report to recreate the various issues which are relevant in the debate. The problem of discounting has been dealt with by using a variety of different discount rates and comparing the sensitivity of the calculated benefit-cost ratios, internal rates of return and present value calculations.

CHAPTER 3

ASSESSING INCREASES IN OFFICER EFFECTIVENESS: A METHODOLOGY FOR MEASURING THE IMPACTS OF MRDS

3.1 Introduction

Any evaluation of program impacts or benefits is ultimately faced with the need to isolate the incremental effects that can be attributed to the program itself. Sorting out genuine impacts (intended as well as unintended) from the "background noise" (McRae, 1984) or the rival hypotheses (Cook and Campbell, 1979) is a process that often challenges the ingenuity of the evaluator.

Evaluating the benefits attributable to the MRDS technology implemented in the Vancouver Police Department is both simple and challenging. Conceptually, it is important to compare policing situations where MRDS is available to those where it is not, and observe the differences in outcomes. Ideally, these comparisons would be conducted so that MRDS and non-MRDS situations would be similar in all important respects, save the presence or absence of MRDS itself. Differences in outcome measures could thus be attributed to the presence or absence of MRDS.

McRae (1984) points out that in Vancouver, an opportunity exists to do this in that only 60% of VPD patrol units are equipped

with MDTs, making it possible, given sufficient resources, to pin down the effects of MRDS through interviews with patrol officers who use the system.

Since the MRDS technology in place in the Vancouver Police Department is intended to yield a voice-free means of accessing CPIC data bases (local and remote), interviews with police officers would need to focus on arrests, and the role (if any) that MRDS plays in generating information necessary to make arrests. Although there would clearly be other reasons for interviewing officers (assessing MRDS effects on perceived safety, for example), a focus on arrests allows the evaluator to get at the system's impacts on officer effectiveness.

Tapping the impacts of MRDS with officer interviews is a costly endeavor. Ideally, a sample of arrests sufficiently large to reliably capture the range of police activities, would need to be coupled with interviews of each arresting officer to debrief that individual on his use (if any) of MRDS in making the arrest. It would be necessary to keep track of arrests as they are reported, and locate and interview each officer as quickly as possible, focusing on the role of MRDS in making the arrest. These interviews could also be used to ask questions about officer safety benefits of MRDS, down time problems (if any) and in general get the user's perspective on this technology.

McRae (1984) outlines a methodology for doing this, but points out that the cost of such a data collection effort would run between $10,000 and $13,000. It would also entail daily contact

between the VPD an least one member of the evaluation team, to follow up arrests while memory of each incident was still fresh.

Funding levels of Phase 2 of the MRDS benefit-cost evaluation precluded debriefing interviews of the sort envisioned in the Phase 1 report. In addition, the problem of quickly following up each arrest with an interview, and obtaining reliable information in sufficient quantities to make this strategy worthwhile as a whole, proved to be insurmountable.

Instead, discussions with Superintendent Kenneth Cocke and his staff focused on the development of a means of obtaining interview data from a sample of arrests, while obviating the costs and logistical difficulties of such a process. The strategy selected involved surveying officers making warrant arrests for enough time to develop a profile of MRDS usage. With the assistance of VPD staff (notably S/Sgt. Larry Richardson), a plan was worked out whereby copies of all booking sheets for arrests made in a given 24 hour period were forwarded from the jail to S/Sgt. Richardson who contacted the arresting officer, sending a copy of a one-page questionnaire to that person and requesting completion of the survey within 5 days. A copy of the survey form is included in Appendix B.

The survey form was designed so that the arresting officer could indicate what type of arrest he had made (criminal, traffic bench warrant, bylaw warrant, and failure to appear), the charge involved (if a criminal arrest was involved), whether his patrol vehicle was equipped with an MRDS unit, whether his MRDS unit had

been used in connection with the arrest, and if it had, whether he would attribute the arrest to his use of MRDS.

The latter question on the survey form was intended to tap the user's perception of the incremental value of MRDS in a particular arrest situation. Incidents where the arresting officer indicated that that arrest was the result of using MRDS were categorized as instances of a key impact attributable to MRDS.

A final question on the survey form asked for officers' experience in MRDS-equipped vehicles, as well as non-MRDS-equipped vehicles over the time they had been members of the VPD. Although the survey form did not solicit comments on MRDS, some officers offered useful observations, a sample of which are presented and discussed in the next Chapter.

The survey of all arrests was implemented on January 1, 1985 and ran until March 20, 1985. Due to some unanticipated delays in starting the project, and the belief that the data collection instrument should only be used for a maximum of 3 months, data was not collected for the months of November and December 1984 as originally intended. As will be seen in the next chapter, the period January 1, 1984 to March 20, 1985 produced sufficient data to generate reliable estimates of the MRD benefits. All arrests made within the patrol division were included in this census effort. Thus, any arrest made by an officer in squads that are wholly or partially equipped with MRDS units was followed up with a survey form.

As surveys were completed and returned to S/Sgt. Richardson, they were checked for completeness and mailed by courier to the University of Victoria. There they were coded, and imputted for the computer-based statistical analysis that forms the core of this Chapter.

3.2 Profile of Arrests

A total of 1463 survey forms were returned and coded. Of those, 1428 (97.6%) were completed in enough detail to be useful for analysis. The survey form was designed to record the details of one type of arrest (either criminal, TBW, bylaw or fail to appear). In a small percentage of arrest incidents surveyed (N=39 or 3.4%) more than one type of arrest was mentioned. For purposes of this discussion it is easier to analyze the first arrest mentioned on the survey forms. A summary of the second arrests mentioned are included in Table A.1 in Appendix A.

Table 3.1 shows that the most frequent type of arrest was a traffic bench warrant arrest, occurring 46.2 percent of the time. This fact has major implications for the utility of MRDS, as many of these arrests occur in incidents where a vehicle check or a driver's licence check is run through the patrol vehicle's mobile data terminal (MDT).

Criminal arrests occurred 35.1 percent of the time. Bylaw arrests were next in frequency, occurring 236 times (16.5 percent). Again, because bylaw warrants are entered into the CPIC data base

that is accessed by MRDS, a potential linkage between these arrests and MRDS usage might be anticipated. Very few arrests were categorized by the arresting officer as failures to appear. For this reason, this category will not be discussed in any detail in subsequent analyses.

TABLE 3.1

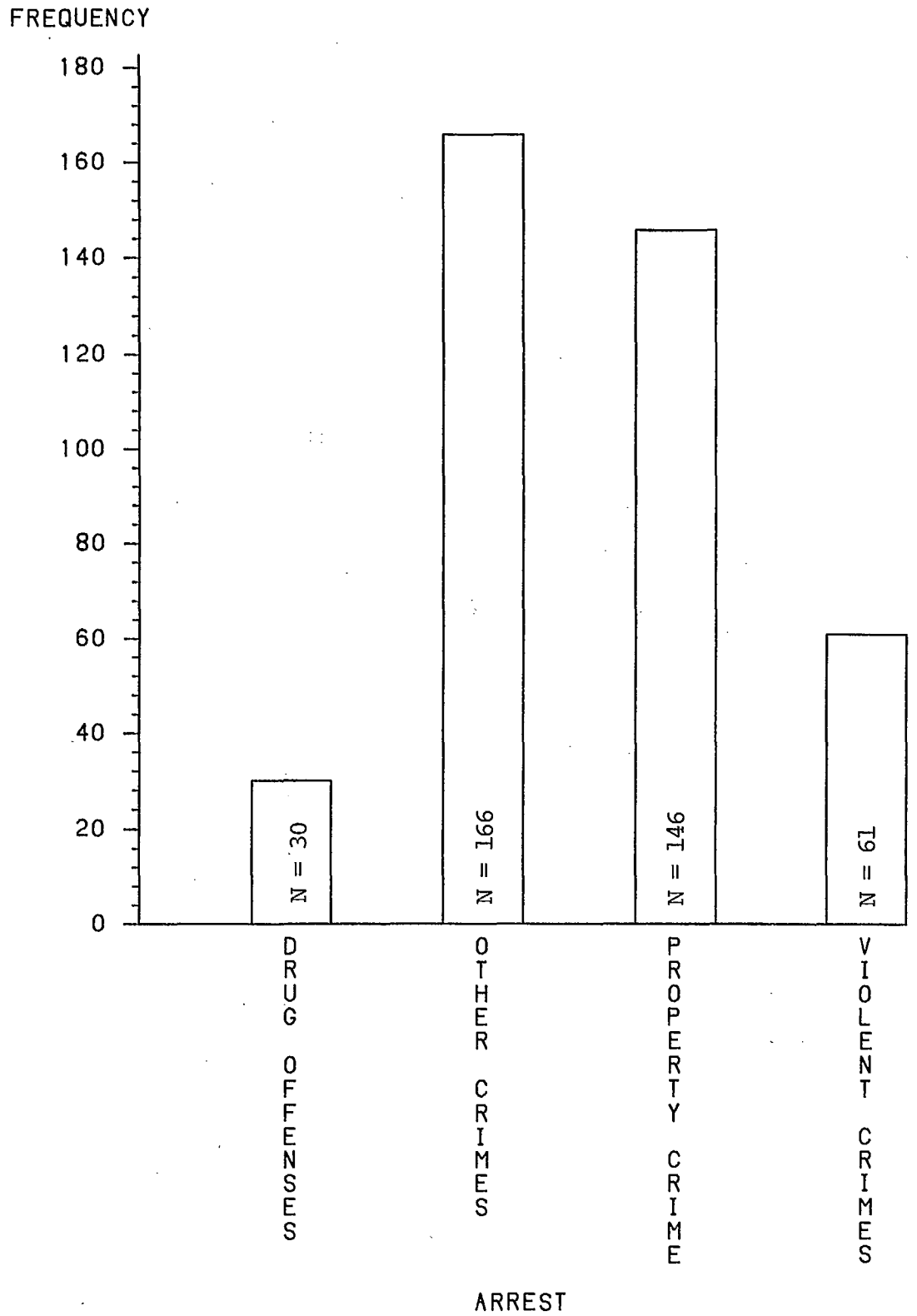
Types of Arrests Recorded in January-March Census

	Criminal	Traffic Bench Warrant	Bylaw	Failure to Appear	Total
Number of Arrests	501	660	236	31	1428
Percentage of All Arrests	35.1%	46.2%	16.5%	2.2%	100%

A wide range of criminal arrests were recorded during the survey. Figure 3.1 displays the relative frequencies of four different kinds of criminal arrests. Statistics Canada conventions for distinguishing violent crimes, property crimes, other criminal code offenses and Federal drug offenses were used. The numbers in the figure do not total to 501 due to missing information on some survey forms.

FIGURE 3.1

CRIMINAL ARRESTS RECORDED DURING THE MRDS SURVEY
1 JANUARY TO 20 MARCH 1985



Within each of these four categories, a range of incidents were recorded. Robberies (N=17) were the most frequent violent crime recorded during the survey period. Theft under $200 (N=59) was the most frequent property offense; impaired driving (N=29) was the most frequent other crime, and narcotics in possession (N=17) was the most frequent drug offense. Table A.2 in Appendix A gives a more detailed breakdown of crimes recorded in the survey.

3.3 Availability and Utilization of MRDS

3.3.1 Criminal Arrests

Each of the four major categories of criminal arrests was analyzed in more detail to obtain a picture of the conditions under which each arrest was made. Specifically, the availability of MRDS for each arrest was recorded by the arresting officer, as well as his use of MRDS, where it was available.

Figure 3.2 presents the breakdown of the four major types of arrests recorded according to whether the arresting officer had access to a MRDS unit. In addition, the utilization of MRDS is displayed, together with the frequency of incidents were the arresting officer felt that the arrest had been made as a result of using MRDS.

FIGURE 3.2

AVAILABILITY AND USAGE OF MRDS FOR CRIMINAL ARRESTS

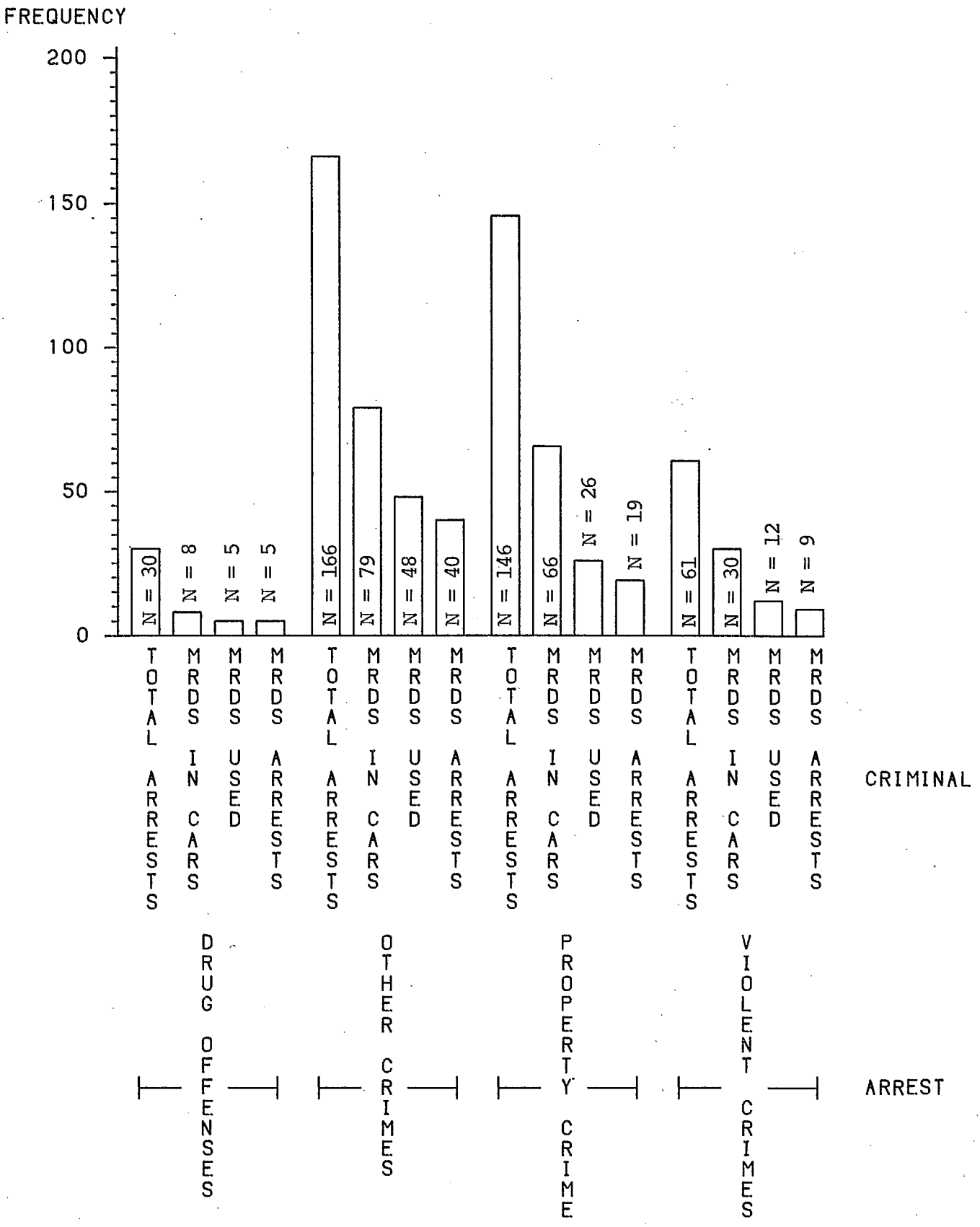
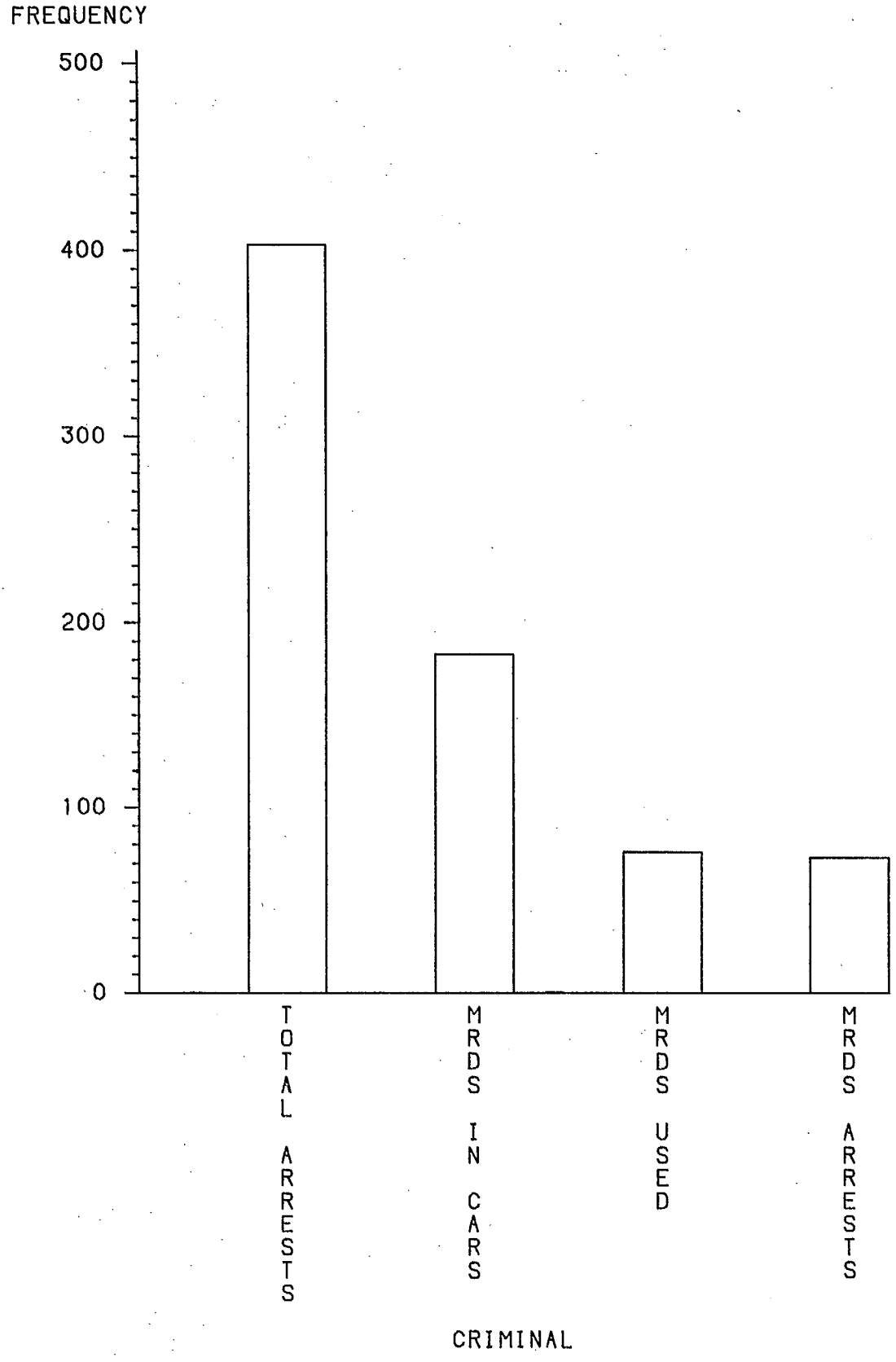


Figure 3.2 suggests that the general pattern of MRDS availability for the criminal arrests surveyed is limited by the availability of MRDS in patrol vehicles. For violent crimes, MRDS was available in 49.2% of arrests made; in 45.2% of property crime arrests; in 47.6% of other crime arrests and only 26.7% of drug arrests. Where it is available, it tends to be used most often for other crimes (48 of 79 incidents or 60.8% of the times it was available) and drug offenses (5 or 8 incidents or 62.5% of the times it was available).

Figure 3.3 summarizes the information presented in Figure 3.2 As the figure shows, MRDS is available in 45.4 percent of all cases where a criminal arrest was made. It is used in 41.5 percent of all cases where it is available and if used, 96.0 percent of the arrests are attributed to MRDS.

FIGURE 3.3

AVAILABILITY AND USAGE OF MRDS
FOR ALL CRIMAL ARRESTS TAKEN TOGETHER

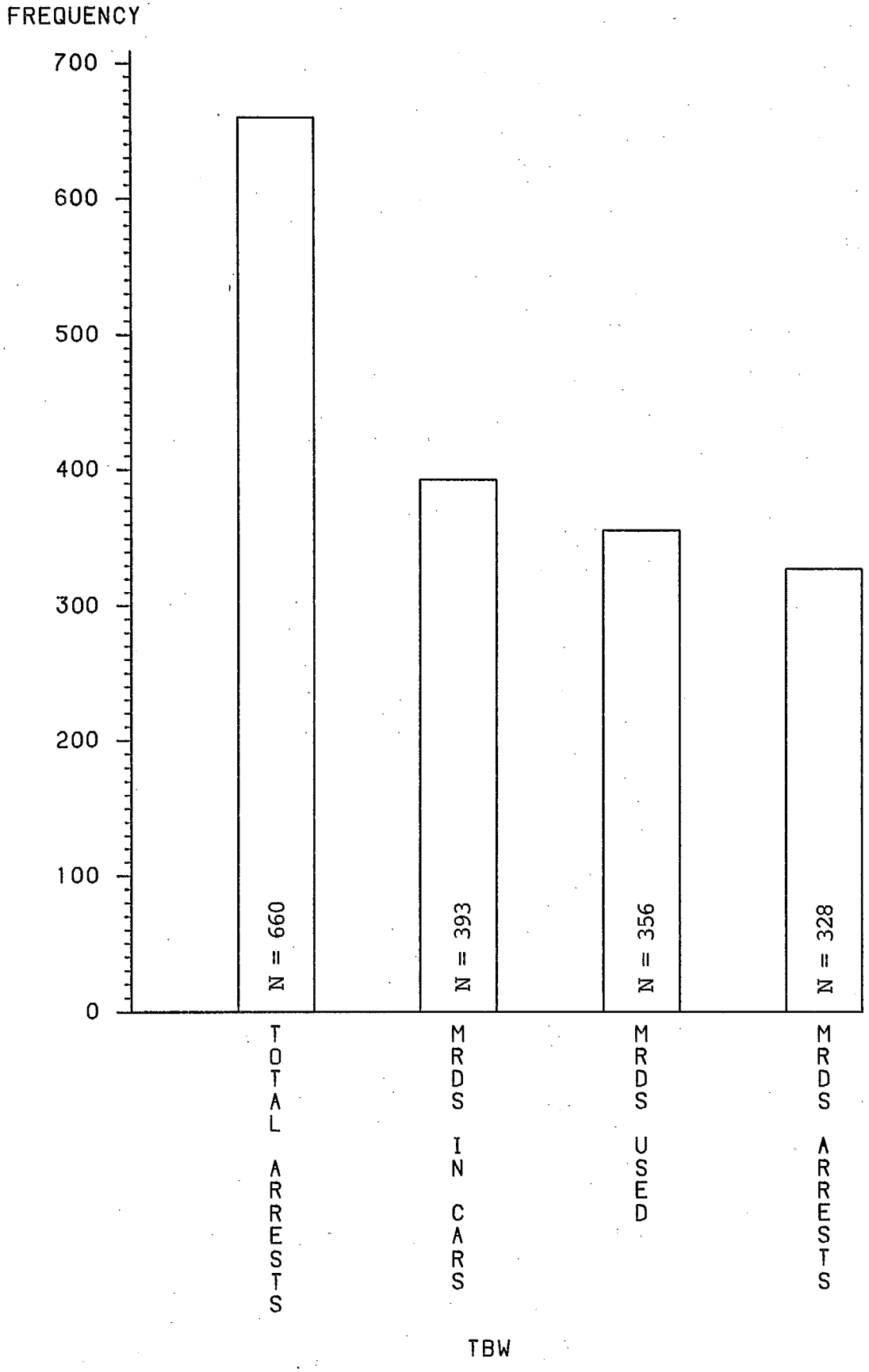


3.3.2 Traffic Bench Warrant Arrests

Figure 3.4 displays the availability and utilization of MRDS for the 660 TBW arrests that were recorded in the survey. As can be seen, MRDS was available in 393 of these incidents (59.5%) and was used in a much higher percentage of cases (356 incidents or 89.9%) than was true for any categories of criminal arrest. This fact suggests that MRDS is strongly connected with TBW arrests. Where MRDS was used, the arrest was attributed to MRDS in a high percentage of cases (N=328 or 92.1%).

FIGURE 3.4

AVAILABILITY AND USAGE OF MRDS FOR
TRAFFIC BENCH WARRANT ARRESTS



3.3.3 Bylaw Warrant Arrests

Bylaw warrant arrests differ from TBW arrests in that the former relate to enforcement of City of Vancouver bylaws whereas the latter pertain to infractions of the Provincial Motor Vehicle Code. The process by which bylaw warrants are issued and entered onto the CPIC data base is analagous to that used for TBWs. Normally, when a ticket is written, the person (or vehicle) ticketed is given the option of paying a fine in lieu of answering a summons. If the fine is paid within the time frame specified by the ticketing officer, the charge is suspended.

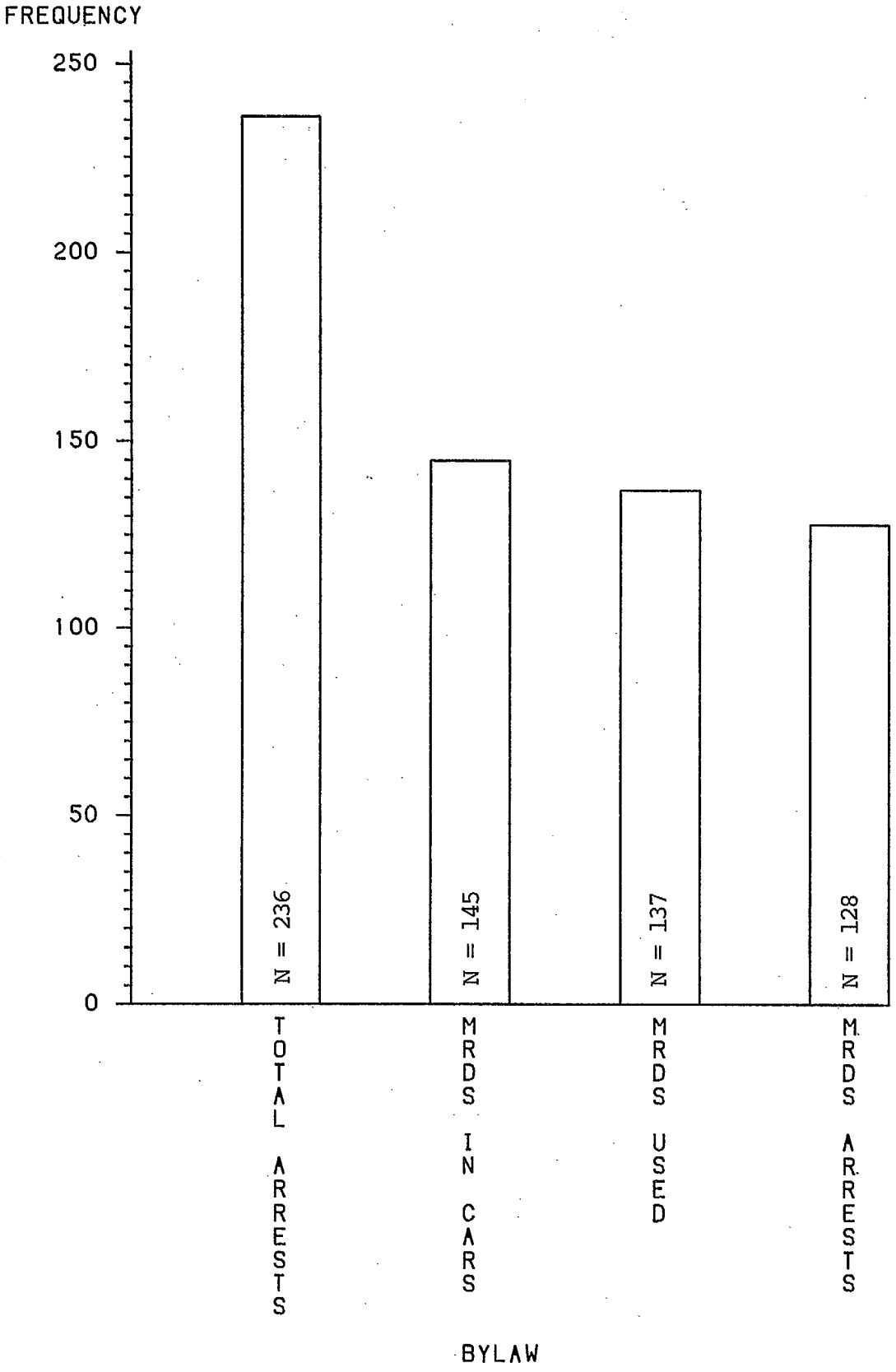
Beyond the ticket's expiry date, it is forwarded to a Justice of the Peace for the swearing of information contained on the ticket. Sworn tickets are then normally mailed out to the person involved as a summons. In some cases, summons are delivered in person (where five or more are being served on the same person at once). If the summons is not answered (the fine is not paid) within a time specified (two to three weeks) then a request for a warrant is made to a Justice of the Peace. Warrants issued are forwarded to the Police Department where they are entered on the CPIC database. Police officers are then able to access them directly via MRDS.

Figure 3.5 presents the findings from an analysis of MRDS usage for bylaw arrests. MRDS was available in N=145 (61.4%) of these arrests, and was used in N=137 (94.5%) of the cases where

it was available. This percentage is even higher than was the case for TBW arrests. Where MRDS was used, the arrest was attributed to MRDS in N=128 (93.4%) of the cases. This percentage is similar to that recorded for TBW arrests (92.1% of MRDS-involved arrests were attributed to MRDS).

FIGURE 3.5

AVAILABILITY AND USAGE OF MRDS FOR
BYLAW WARRANT ARRESTS



3.4 Summary

The survey findings suggest that MRDS is used most frequently in TBW and bylaw warrant arrests. In fact, as Table 3.2 shows, 49.7% of all TBW arrests are attributed to MRDS. An even higher percentage of all bylaw warrant arrests (54.2%) are attributed to MRDS. These findings contrast with those for different kinds of criminal arrests. MRDS usage is lower for all categories of criminal arrests, and the percentages of arrests attributable to MRDS are much lower as well.

It is clear from these findings that a principal source of benefits associated with MRDS is the level of TBW and bylaw warrant arrests attributed to MRDS. Since these arrests normally yield revenue for either the Provincial Government (in the case of TBW arrests) or the City of Vancouver (bylaw arrests), it is possible to estimate the monetary benefits associated with the use of MRDS for making these arrests. That will be a principal task of the next chapter.

TABLE 3.2

Numbers and Percentages of All Arrests Attributed to the Use of MRDS

	Violent Crimes	Property Crimes	Other Crimes	Drug Offenses	Traffic Bench Warrant Arrests	Bylaw Warrant Arrests	Total Arrests
No. of Arrests	61	146	166	30	660	236	1299*
No. of Arrests Due to MRDS	9	19	40	5	328	128	529
% of Arrests Due to MRDS	14.8%	13.0%	27.4%	16.7%	49.7%	54.2%	40.7%

*This total is less than that reported in Table 3.1 because 98 criminal arrests were not specified as to type, and 31 failure to appear arrests are not included in this table.

Although criminal arrests are less frequently attributed to MRDS, it is noteworthy that some of each kind of arrest are attributed by arresting officers to their use of MRDS. In fact, over 25% of other crime arrests are attributed to MRDS. Valuing the benefits from these arrests is much more difficult, and no satisfactory way exists for converting a criminal arrest of a given type into a monetary benefit. Nevertheless, it is important to discuss these arrests and at least identify the types of criminal arrests that are linked to MRDS technology by its users. This will also be a topic in the next chapter.

CHAPTER 4

ESTIMATES OF THE BENEFITS FROM MRDS

4.1 Introduction

A benefit-cost analysis of a technological innovation like MRDS reveals two principal types of benefits: those that are tangible and those that are not. The former lend themselves relatively well to the methodology of benefit cost analysis. That is, by developing a means of measuring the magnitudes and types of outcomes attributable to MRDS, and then estimating the dollar values of these outcomes, it is possible to obtain a picture of how large a return on the investment has been obtained over the years MRDS it has been in place. Furthermore, by extrapolating the benefits stream into the future, it is possible to estimate the net present benefits over the forseeable life of the technology.

Intangible benefits are equally important, and a complete benefit-cost analysis needs to take them into account. It is clearly an error to omit discussion of benefits attributable to MRDS simply because they do not readily translate into dollar values.

In the discussion which follows, an effort will be made to develop and use a methodology for converting the tangible benefits

into dollar figures. Other benefits will be treated qualitatively, that is, evidence for their importance will be presented and discussed, but no attempt will be made to assign monetary values to them.

This analytical strategy is intended to be conservative, erring overall on the side of undervaluing the benefits. Given the methodological issues inherent in any assessment of benefits from a program which impacts in part on the quality of the working environment (as MRDS does) a conservative strategy in estimating benefits is more defensible.

4.2 Valuing the Benefits From TBW and Bylaw Arrests

Table 3.2 in Chapter 3 indicates that officers having access to MRDS units attribute 49.7 percent of traffic bench warrant arrests and 54.2 percent of bylaw warrant arrests to MRDS usage. These figures, based as they are on a census of arrests from January 1 through March 20, 1985, provide a basis for estimating the impact MRDS has had on these two types of arrests over time. By using Vancouver Police Department records, as well as records provided by the Court Services Branch of the British Columbia Ministry of the Attorney General and the Bylaw Fines Collection Office of the City of Vancouver, it is possible to estimate the incremental effect of MRDS on TBW and bylaw warrant arrests from 1980 when MRDS was implemented through the end of 1984.[1]

Vancouver Police Department records of warrant arrests treat TBW and bylaw arrests together over time, making it necessary initially to aggregate the percentage of arrests attributed to MRDS for TBW and bylaw warrant arrests. Thus, the percentages of TBW arrests, and bylaw arrests attributed to MRDS (49.7% and 54.2% respectively) had to be combined by taking a weighted average of the percentages. Overall, TBW and Bylaw Warrant arrests are attributed to MRDS 50.9% of the time.[2]

Column 1 of Table 4.1 indicates that all the officers who attributed either their TBW or bylaw arrests to MRDS indicated they had experience in vehicles that did as well as those that did not have MRDS on board. Thus, when officers attribute arrests to MRDS, they make this judgment having had experience in both types of cars.

TABLE 4.1

TBW and Bylaw Arrests Attributed to MRDS by Officer Experience with MRDS-Equipped and Unequipped Vehicles

	Arrest Attributed to MRDS				
	Yes	No	MRDS Not in Patrol Vehicle	Missing Data	Totals
Experience with Both Types of Vehicles	454	78	345	8	885
Experience with MRDS vehicles only	0	0	0	0	0
Experience with non-MRDS vehicles only	0	0	2	0	2
Missing Data	4	2	3		9
TOTALS:	458	80	350	8	896

MRDS was implemented in its current expanded version on July 12, 1980. It is unreasonable to assume that the system worked as intended, as soon as it was in place. More likely is a shakedown period during which electronics components, software components and human operators become familiar with the technology and its capabilities. To factor in such a starting period, it is reasonable to begin calculating benefits at some point after the July 12 starting date. Picking such a date is somewhat arbitrary, but it is prudent to be conservative. No benefits attributed to MRDS will be calculated before September 1, 1980.

Estimating the volume of TBWs and bylaw warrants that would flow through the system during the September-December period of 1980 requires monthly information on the volume of such activity. Direct information is difficult to obtain, given the age of the data required. Instead, an estimate of the number of TBW and bylaw arrests was based on the volume of Traffic Ticket Informations (TTIs) and Bylaw Informations received by the Court Services Branch of the Ministry of the Attorney General. For the months of September through December of 1982, 1983, and 1984, the numbers of TTIs and Bylaw Informations issued were totalled, and a ratio with the yearly levels was calculated. Based on this process it was estimated that 34 percent of the TBW and bylaw arrests would have occurred from September through December, 1980.[3]

Table 4.2 displays the yearly levels of TBW and bylaw warrant arrests by the Vancouver Police Department from 1980 through 1984. The figures suggest a gradual increase in the volume of these arrests over the five year period. Between 1980 and 1984, there was a 29.6% increase in these kinds of arrests.

TABLE 4.2

Year-End Totals of Traffic Bench Warrants and Bylaw Warrant Arrests

Year	Frequency
1980	5806
1981	6834
1982	6404
1983	6831
1984	7528

These figures, combined with information from the MRDS survey, make it possible to generate an estimate, for each year, of the number of TBW and tylaw warrant arrests attributable to MRDS. It is clear that this estimating process depends for its credibility on the representativeness of the survey findings, with respect to other seasons and other years, and on the accuracy of the figures presented in Table 4.2. As well, the estimates of MRDS-related arrests depend upon the validity and reliability of the judgments made by system's users, as expressed in the survey findings.

Table 4.3 presents the annual numbers of TBW and bylaw arrests attributed to MRDS, based on the data and the assumptions set forth to this point. The number of arrests attributed to MRDS during 1980 is 50.9 percent of 34 percent of that year's frequency. Thus, the proportion of warrant arrests attributed to MRDS (50.9%) has been used to estimate the actual number of arrests due to MRDS in 1980, as well as the four subsequent years.

TABLE 4.3

Annual TBW and Bylaw Warrant Arrests Attributable To MRDS Usage

Year	Period of Benefits	Frequency of Arrests	Arrests Due to MRDS[4]
1980	Sept 1 - Dec 31	5806	1005
1981	Full year	6834	3478
1982	Full year	6404	3260
1983	Full year	6831	3477
1984	Full year	7528	3832

4.3 Estimates of the Annual Dollar Benefits Associated With TBW and Bylaw Arrests

Traffic bench warrant and bylaw arrests are made for infractions of the Provincial Vehicle Code and City of Vancouver bylaws, respectively. Fines for offenses under the Provincial Vehicle Code vary considerably. The range of fines reported by Court Services Branch varies from a minimum of $10.00 to a maximum of $350.00. Any given traffic ticket, written with reference to the Vehicle Code could have a monetary value anywhere in this range. Most tickets however, are somewhat larger than the minimum, but far less than the maximum. Direct estimates of the average fine on a ticket are not possible, given the manner in which records are currently kept. That is not to say that records are

inadequate - they simply do not meet the needs of this evaluation. It is therefore necessary to estimate the average of a traffic ticket written. Given the importance of this estimate, it is prudent to use a range of values, computing benefits with both the minimum and maximum fines. The range suggested by the Court Services Branch is $25.00 to $30.00 per ticket.[5] Thus, $25.00 can be viewed as a conservative estimate of the revenue per TBW ticket, and $30.00 as an upward limit in a range of possible revenues per ticket.

A similar problem exists for bylaw offenses. No statutes are available which permit a direct estimate of the average value of a bylaw ticket. It is possible, however, to use information available on the number of court trials involving bylaw offenses, and the statutory value of each offense to help estimate a range of values for bylaw arrests.

Table 4.4 displays the number of trials scheduled by the Court Services Branch from August 1984 through February 1985 that involved bylaw offenses. Each "trial" focuses on a separate ticket written, so it is possible to have one person being tried for several offenses at once.[6]

TABLE 4.4

Trials Scheduled For Bylaw Offenses in Vancouver

	Tickets Issues By Meter Maids	Tickets Issued by Police Officers
August 1984	36	69
September	141	118
October	428	313
November	261	234
December	200	157
January	292	222
February 1985	221	158
TOTALS:	1579	1271

Each ticket issued by a meter maid has a statutory value of $25.00 at the time of the trial, and each ticket issues by a police officer has a value of $30.00. It is possible, given this information, to estimate an average value for each trial. By totalling the trials, and weighting the total to take account of the difference in ticket values, an average of $27.77 per trial is calculated. This figure, however, is spuriously precise, and it is more defensible to employ the same range ($25.00 to $30.00) as was employed for offenses committed in violation of the Provincial Vehicle Code.

One more estimation problem remains. Even when a police officer arrests an individual on a TBW or bylaw warrant, it is possible that the offense for which the person was arrested will be

settled before a trial occurs. Indeed, by paying the statutory fine before the trial date, a person is able to terminate the judicial process. Thus, of all TBW and bylaw arrests made, only a minority end up in court. Again, it is not possible to access statistics that directly estimate the proportion of all arrests that go to a court trial. However, Court Services Branch estimates that 30% of those arrested on warrants contest the case through to a trial. Of those cases that do go to court, approximately 60 percent generate the statutory penalty as revenue. The rest result in one of a number of outcomes: suspension of the fine, ticket withdrawn because the ticketing officer does not appear, case dismissed due to lost documents or changes in statutes and bylaws or precedents set through previous cases.

Given the estimates discussed to this point, and the data obtained from the Vancouver Police Department (the MRDS survey and annual TBW/bylaw warrant arrest totals) it is possible to calculate a range of monetary benefits attributable to MRDS.

Table 4.5 provides the necessary statistics and computations to estimate a minimum and maximum benefit of MRDS from TBW and bylaw warrant arrests. These benefits are tangible, expressed in nominal dollars for each of the years that MRDS has been in place. Later in this report, it will be appropriate to discount these figures, as well as the costs of MRDS, to obtain an estimate of the net benefit attributed to the system.

TABLE 4.5

TBW and Bylaw Warrant Arrest

Estimated Ranges of Benefits Attributed to MRDS, 1980-1984

	A Warrant Arrests Attributed to MRDS	B Warrant Arrests Not Going To Trial[1]	C Warrant Arrests Going to Trial	D Warrant Arrests Yielding Revenue From Trials[2]	E Warrant Arrests Yielding Revenue[3]	F Minimum Estimate Revenue[4]	G Maximum Estimate Revenue[5]
1980	1005	704	301	181	885	22125	26650
1981	3478	2435	1043	626	3061	76525	91830
1982	3260	2282	978	587	2869	71725	86070
1983	3477	2434	1043	626	3060	76500	91800
1984	3832	2682	1150	690	3372	84300	101160

1 .7 of Column A figures

2 .6 of Column C figures

3 Column B plus Column D figures

4 Column E times $25.00

5 Column E times $30.00

4.4 Dispatcher Labour Savings

A second category of tangible benefits exists. In a report from the City Manager's office (May 11, 1979), reference is made to the impact of MRDS on the workload of the dispatchers. In sum, the report indicates that the workload of dispatchers will be reduced significantly. Inquiries that can be routed directly through the MRDS system would free up the dispacher time utilized for status updates, vehicle checks, and person checks. The estimated saving in dispatcher labor costs with the implementation of MRDS was $99,000.00 annually.

When the system was implemented in July 1980, voice channel communications (an indicator of demand for dispatcher time) actually increased by 6% (McRae, 1984, p. 32). At the same time however, the equivalent of two additional voice channels were added with the introduction of MRDS (McRae, 1984, p. 33). Thus, a substantial increase in data base inquiries was supported by existing personnel. If those inquiries (averaging 50,000 per month) were all routed though voice channels, additional dispatchers as well as additional voice radio communications capacity would need to be purchased.

Valuing the implementation of MRDS as equivalent to saving $99,000.00 in labor costs, rests in part on the assumption that the

marginal value of additional data base inquiries due to MRDS is similar, from patrol officers' perspective as are inquiries made over the air. Studies of digital communications systems in Oakland and Palm Beach in the United States have pointed out that officers with access to digital technology view the costs of information retrieval as very low. Hence, they use the technology to make mass data searches (McRae, 1984, p. 31), knowing that the marginal value of these inquiries is very low - resulting in few arrests and charges. If these inquiries were priorized by having to air them over a voice channel, many fewer would be made.

In Vancouver, there is no direct evidence for the phenomenon of mass data searches. McRae (1984, p. 31) reports that experience with MRDS is that inquiries made are based on similar criteria as are voice-based inquiries. Thus, MRDS has apparently expanded communications in a way which could only be sustained (in the absence of MRDS) with additional dispatch personnel.

Table 4.6 presents annual benefit estimates that combine the estimates included in Table 4.5 with the labor cost savings due to the implementation of MRDS. It is worth noting that over time, the cost saving estimate becomes more conservative, as inflation and other salary-related factors operate to boost labor costs.

To estimate future benefits that will be used in the benefit-cost calculations in Chapter Six, benefits from 1981 through 1984 were averaged and projected through 1989. They are indicated as projected benefits in Table 4.6. Because annual totals of TBW and bylaw arrests were not disaggregated by the

Vancouver Police Department, the columns in Table 4.6 are the most disaggregated form in which annual benefits can be presented.

TABLE 4.6

Combined Benefits From TBW and Bylaw Warrant Arrests and Labor Cost Savings

	Minimum Estimated Benefit	Maximum Estimated Benefit
1980	55785	60310
1981	175525	190830
1982	170725	185070
1983	175500	190800
1984	183300	200160
1985*	176275	191715
1986*	176275	191715
1987*	176275	191715
1988*	176275	191715
1989*	176275	191715

*Projected benefits

4.5 Intangible Benefits of MRDS

Benefit-cost analysis is a powerful evaluation technique precisely because it yields a monetary estimate of the net present benefit of a program or project. For managers, this "bottom line": is a useful information. But the technique demands a great deal of data to fully value the benefits from a program.

This evaluation of MRDS is typical of many benefit-cost analyses in that benefits can be identified for which there is no defensible methodology for translating them into dollar figures. Indeed, it is arguable that the most important benefits fall into this category.

Discussions with members of the Vancouver Police Department, and unsolicited comments from officers who completed MRDS survey forms suggest that there is a strong consensus that MRDS is an indispensible tool in policing Vancouver. By way of illustration, it is worthwhile to quote several (anonymous) survey responsents, regarding their evaluations of MRDS.

> "MRDS is an excellent system, it should be in all vehicles, including regular patrol unmarked vehicles. MRDS has been instrumental in over 18 arrests for my partner and I over the last few months."
>
> "When vehicle is equipped with MRDS I use it for all 10-29, 28 and 27's. A practical and valuable tool from a patrol stand point!"
>
> "MRDS should be installed in both marked and unmarked patrol vehicles, it is an excellent tool!"
>
> "We walk the Davie beat and haven't been given an MRDS to use for 2 years. We'd use it if we had it though!"

These comments suggest that MRDS is viewed very positively and that officers believe the system should be expanded. The benefits that are perceived by members of the Vancouver Police Department can be classified as safety and productivity benefits.

4.5.1 Safety Benefits

Clearly, part of the reason for MRDS's support in the VPD is an officer's ability to gather information on a vehicle before actually pulling it over and approaching it on foot. Any indication that the vehicle or its owner is suspicious, connected with a previous criminal offense or otherwise "hot" can be used by the officers immediately. Although it was not possible to document cases where officer injury had clearly been avoided by using the information provided via MRDS, it is clear that MRDS is viewed as a means of reducing the danger associated with apprehending suspected individuals or vehicles.

4.5.2 Productivity Benefits

Although MRDS has already been linked to TBW and bylaw warrant arrests, it is also true that officers attributed criminal arrests to MRDS. Recalling the statistics summarized in Figure 3.2 in the previous Chapter, 9 arrests for violent crimes, 19 arrests for property crimes, 40 arrests for other criminal code offenses and 5 drug arrests were attributed to MRDS.

Calculating a monetary benefit for these arrests would entail estimates of the savings to the public and the criminal justice system of apprehending an individual. For example, 7 of the 9 violent crime arrests where MRDS was identified as the reason for the arrest, were assaults. Bodily injury and attendant medical expenses, emotional trauma, and loss of work

income are several obvious costs to individuals who have been assaulted. Arresting an individual on an assault charge sets in motion a criminal justice process that may result in a wide range of outcomes. The person arrested may be tried, found guilty and imprisoned. If this happened, it might be argued that other assaults (and their attendant costs) that that person may have perpetrated during the time he was "out of circulation" were prevented. Assaults prevented can be viewed as benefits, and if the arrest were attributed to MRDS, the benefits might also be attributed to MRDS.

Such reasoning is clearly speculative and cannot be supported in this analysis. Much more data would need to be gathered, and the scope of this benefit cost analysis would need to be expanded greatly.

It is worth noting that benefit cost analyses have been done where cost savings (defined in the studies as benefits) have been identified because a program has caused a reduction in criminal activities. An example of such a study is the Perry Preschool Evaluation, completed by the Hi-Scope Education Foundation in Ypsilanti, Michigan.[7] The principal investigators in that project set up a randomized research design wherein half of a group of 120 black children (aged 3 and 4) received preschool education, and the other half did not. These children were followed through high school into adulthood, and measurements of the impacts of the program were taken along the way.

One set of measures, gathered from interviews with the participants, police records, court records, and interviews with the parents, focused on interactions between the children (now young adults) and the criminal justice system. By recording the numbers of different offenses committed by persons in the preschool and non-preschool groups, the evaluators were able to generate sufficient data to estimate the numbers of offenses that had been prevented by the program. Estimates of the costs (to the criminal justice system) of handling an offense of a given type were used to calculate the net savings to society of the 60 children having the experience of preschool.

The methodology of that study is elegant but points out clearly that much more information than is available from the MRDS study is needed to calculate savings to society from having arrested one person for assault.

It is possible to describe the criminal arrests attributed to MRDS. Table 4.6 lists the types and frequencies of arrests made. The range of offenses is quite broad, indicating that MRDS is being used in a variety of situations.[8]

TABLE 4.7

Types of Charges in Criminal Arrests Attributed To MRDS

Violent Crimes	Frequency
Assault	5
Assault With a Weapon	2
Aggrevated Assault	1
Robbery	1
	9
Property Crimes	
Breaking and Entering	2
Attempted B & E	1
Auto theft	1
Theft Over $200	1
Theft Under $200	7
Possession of Stolen Property	3
Fraud	4
	19

Other Crimal Code	Frequency
Criminal Mischief	1
Impaired Driving	7
Driving Over 80 km	2
Prohibited Driver	2
Obstructing an Officer	2
Breach of Probation	4
Breach of Bail	2
Unlawfully at Large	1
Hit and Run	1
Income Tax Act	1
Liquor Act	1
Warrant of Committal (unspecified)	13[9]
Other Charges	3
	40
Federal Drug Offenses	
Possession for purposes of trafficking	1
Narcotics in possession	4
	5

The main feature of Table 4.7 is the fact that the arrests indicated are attributed by the arresting officer to MRDS. If these arrests would not have occurred otherwise, then there is a clear improvement in the productivity of police officers across a range of criminal apprehension activities. Over time this productivity difference becomes substantial. Although it is not possible to translate these arrests into monetary benefits or

savings to society, they cannot be ignored in an assessment of benefits from MRDS.

4.6 Summary

Some of the key benefits from MRDS cannot be quantified in a defensible manner. It is necessary instead to describe them as fully as data permit, and offer their inclusion as a qualification of any calculation of net present benefits.

Aside from the safety and productivity benefits just discussed, one other benefit needs to be included. MRDS offers a means of bringing persons to justice who would otherwise avoid being arrested. The speed with which queries of the database can be made and responded to, enhance the use of information in police patrol activities. From a citizen's perspective, MRDS can be viewed as a deterrent. Indeed, discussions with members of the VPD and the City of Vancouver Bylaw Fines Collection Office pointed to the fact that a warrant for the arrest of someone is the ultimate step in the process of bringing bylaw violators into the criminal justice process. Having those warrants on MRDS means that these persons, having in most cases been warned by earlier steps in the process, can be arrested under a variety of conditions by any member of the VPD that has access to an MRDS unit. This may have a deterrent effect, through repeated demonstrations that the VPD does have a means of arresting individuals who ignore the judicial process.

Benefits from MRDS during its first five years of operation can be itemized as follows:

- Increased frequencies of traffic bench warrant arrests and hence, revenue for the Province of British Columbia.
- Increased frequencies of bylaw warrant arrests, resulting in increased revenues for the City of Vancouver.
- Savings due to not having to hire additional dispatch personnel to handle MRDS-based inquiries.
- Increased frequencies of criminal arrests.
- Improvements in officer safety.
- Some deterrence effect vis the public at large.
- A strong sense among officers of the VPD that MRDS is an important tool, and implicitly a boost to officer morale as well as officer effectiveness.

This last point can be expanded briefly by referring again to the unsolicited comments made by officers completing the MRDS survey forms. Most comments suggested the system be expanded to include all marked and unmarked patrol vehicles. The only negative comments about MRDS focused on its not being available at all times - "down time" was cited as a frustration in situations where officers wished to use the system.

FOOTNOTES

1. Staff Sgt. John W. Unger of the Vancouver Police Department, P. Joan Furnival of the Court Services Branch of the Ministry of the Attorney General and June J. Bitzkal of the Bylaw Fines Collection Office were very helpful in providing information used in this analysis.

2. This percentage is arrived at as follows: 660 TBW arrests + 236 Bylaw arrests = 896 total. Of these arrests, 328 + 128 = 456 were attributed by arresting officers to MRDS. Overall percentage = 456/896 = 50.9 percent.

3. Supporting statistics are provided in Table A.3, Appendix A. The statistics in Table A.3 provide information which is useful to proxy the proportion of TBW and bylaw arrests that occurred in the September through December period of 1980.

4. These calculations are made by multiplying the annual total of arrests by the proportion the users attributed to MRDS, in the survey (0.509).

5. This information was provided by Joan Furnival, Court Services Branch, Ministry of the Attorney General.

6. This data was provided by Joan Furnival, Court Services Branch. It should be noted that these trials may result from a person contesting a ticket, and demanding further judicial review of the circumstances. These latter cases would not be reflected in police records of TBW or Bylaw Warrant arrests.

7. John R. Berreuta-Clement, et.al, Changed Lives: The Effects of the Perry Preschool Program on Youths Through Age 19 (Ypsilanti, Michigan: Hi-Scope Educational Foundation, 1984).

8. One limitation of the data displayed in Table 4.6 is the brief descriptions of charges that officers provided. In some cases, it was not possible to classify the charge.

9. It is possible that some of these arrests are misclassified in that a Warrant of Committal can be issued for persons and property charges as well as other criminal code offenses.

CHAPTER 5

MRD SYSTEM COSTS

5.1 History of the System

In June, 1971, the Vancouver City Council employed a private communications consulting firm (Systech Corporation) to examine the City's communications needs for the next 15 years. A review of the projects recommended by the Systech Report was carried out by the City Engineer, the Chief Constable, the Fire Chief and the Director of Finance. The review stressed the urgency of required improvements to the Police communications system. The deficiencies in the existing Police communications system included:

- All requests by patrolmen for checks of lists of wanted persons, stolen vehicles or stolen property could not be handled.

- Response to requests for service from the public and from patrolmen was often slowed, resulting in complaints and increased danger to public and patrolmen.

- Records collected did not provide sufficient information on an up-to-date basis for planning efficient deployment of patrol resources.

The final report of this review committee was submitted to the Standing Committee on Finance and Administration in May, 1973. It recommended adoption of the 911 common emergency number, and an increase in the number of communications channels from two to four. These recommendations were accepted by the Vancouver City Council.

Because of the implications which these decisions had on the VPD's current radio system, telephone system, architectural conditions and operating methods, and the close relationship which exists between the 911 and other PCC technologies, a Communications Study Group was formed. After a series of visits by Study Group members to several major cities to examine communications systems and automated police functions, the Study Group produced a report entitled Police Communications Centre Proposal in October, 1974. This Report outlined the need to sequentially proceed on four fronts.

Phase 1 Develop a revised manual system of dispatching to operate in parallel with the proposed MRD System. The implementation of this change required the construction of a new communications centre within the Public Safety Building to reduce internal and external noise levels, and to increase security and work flow. The revised manual system was made operational in March, 1976.

Phase 2 Install a minicomputer system in the new communications centre to provide direct messages and checks to and from police car terminals. A by-product output of the minicomputer is the collection of basic management information related to the 911 technology. The minicomputer was installed in November, 1978.

Phase 3 Purchase a trial group of 12 mobile terminals for installation in District One patrol units. After extensive in-service testing, this phase of the system was accepted by the Engineering and Police Departments in May, 1979.

Phase 4 Purchase of an additional 48 mobile terminals for installation in patrol units operating in all four policing districts. The full system was operational in July, 1980, with 50 terminals installed in patrol units, and 10 kept as spares.

In order to facilitate the phased introduction of these changes, the Vancouver City Council, in December, 1976 approved the local firm of Macdonald, Dettwiler and Associates (MDA) as suppliers of a digital communications system for the VPD.

5.2 MRD System Costs

A contract between the City of Vancouver and MDA dated April, 1978 summarizes the cost data required to proceed up to the end of Phase 3. See Appendix C for complete cost details.

1.	Communications Centre Equipment		
	. DEC Minicomputer	$ 96,953	
	. MDA Supplied Equipment and software	42,923	
	Total Communications Centre		$ 139,876
2.	Digital Radio Equipment		
	. Communications Centre	$ 10,737	
	. Grouse Mountain Site	17,738	
	Total Digital Radio Equipment		$ 28,475
3.	Mobile Data Terminals and Radios		$ 76,980
4.	Installation Costs		
	. Communications Centre	$ 13,772	
	. Digital Radio Channel	14,120	
	. Mobile Data Terminals	1,469	
	Total Installation Costs		$ 29,361
5.	Other charges		
	. Supervisory Staff Orientation	$ N/C	
	. Miscellaneous Charges	3,000	
	. Optional Equipment for all Management Information System ($3,127) not included	N/C	
	Total Other Charges		$ 3,000

To complete the installation of the MRD System, the City of Vancouver entered into a second contract with MDA in July, 1979. For this final phase, the City returned the 12 Motorola MODAT

mobile data terminals which had originally been installed. Problems with breakages in the alphanumeric keyboard, and the effects of bright sunlight on the legibility of transmitted messages are the reasons stated for removing these particular terminals. These Motorola terminals were traded, minus normal depreciation, for 12 mobile data terminals (model UMCT) manufactured by International Mobile Data Inc. of Richmond, B.C. Forty-eight additional terminals were purchased, to bring the total number of terminals to 60. Additional costs to the City are as follows:

6.	Additional Communications Centre Equipment . MDA Supplied Equipment		$ 25,957
7.	Mobile Data Terminals . 48 UMCT Mobile Data Terminals at $5,747 each	$ 275,856	
	. 12 MODAT Data Terminals returned to MDA in exchange for 12 UMCT units	N/C	
	Total Cost for Data Terminals		$ 275,856
8.	Installation Costs . Communications Centre	$ 1,898	
	. Engineering Supervision and checkout	15,440	
	Total Installation Costs		$ 17,338

The trial and demonstration period involved in Phase 3 used Police Department staff. As shown in cost item 5, MDA agreed to assist the VPD instructors in providing training courses at no charge to the City. However, because supervisory personnel, and a limited number of operational staff, were involved in these courses, the value of their time must be included as part of the

set up costs of the system. These "opportunity" costs have been estimated as follows:

9. Staff Costs

• Mobile terminal operation, 2 sessions (2 separate groups)	$ 400	
• Dispatcher/Information support operation, 2 sessions (2 separate groups) for 1 day each	650	
• System manager terminal operation, 1 session for 2 days	325	
Total Staff Costs		$ 1375

10. Maintenance Charges

- $3,254/month for the period May 1979 to July 1980
- $2,985/month for subsequent years.

5.2.1 Cost Summary

Because different phases of the system were introduced in different years, this cost summary arranges system costs in terms of the approximate year in which they were incurred. The costs are then inflated to 1980 dollars by means of the Consumer Price Index. The year of 1980 was chosen because this is the first year for which benefit estimates are available.

TABLE 5.1

SUMMARY OF COSTS BY YEAR

Year	Cost Items	Total Costs	Cost in 1980 Dollars
1978	1,2,3,4,5,9	$ 279,067	$ 304,462
1980	6,7,8,10	$ 384,198	$ 384,198
		Total Cost	$ 688,660

Thus, the total system cost to 1980, expressed in terms of 1980 dollars, is $688,660. For the years subsequent to 1980, the only additional cost is a maintenance fee of $35,820 per year.

Finally, these cost figures do not include any of the development costs paid for by the Federal Government, Department of Communications. The referent group for this study is the Province of British Columbia. Thus, any costs or benefits which can be assigned to institutions or organizations outside of the Province are ignored in the benefit-cost calculations. As discussed in Chapter 4, most of the estimated financial benefits accrue directly to the Province; thus, no effort has been made to separate out potential benefits which may be captured in other political jurisdictions. In a similar fashion, only costs borne by the Province of British Columbia, or institutions and organizations resident in British Columbia, are included in the analysis. However, for costs, the Federal Government has

financially contributed to this project on three separate occasions.

1. A $600,000 grant from the Department of Communications (Ottawa) to Macdonald, Dettwiler and Associates paid for all software development costs for digital transmission.

2. The Federal Government contributed $50,000 towards purchase of the DEC Minicomputer for the Communications Centre. See Appendix C.

3. The Department of Communications (Ottawa) paid $45,000 to Macdonald, Dettwiler and Associates to adapt the software so that the MRD System could run with the UMCT terminals instead of the Motorola MODAT version.

None of these costs has been included in the calculations, because they are deemed to come from outside of the referent group of British Columbia. By not including those costs directly in the benefit-cost calculations, we are implicitly stating that they are infrastructure costs in the same sense that bridges, roads, airports and research and development expenditures are infrastructure. In other words, the resource costs involved in fundamental research and development are deemed to be common property, and are not factored into the price of every product which makes use of the information.

Other applications of this technology in the taxi, courier and warehousing industries will have the benefit of this basic infrastructure research done by the Department of Communications (Ottawa). However, it must be remembered that applications of this technology to other uses will still require specialist development costs which will have to be borne by the interested firm.

CHAPTER 6

COMBINING THE BENEFITS AND COSTS OF MRDS

6.1 Introduction

Thus far, separate discussions of the benefits and costs of MRDS have laid the groundwork for an analysis of the overall benefit-cost results of this study. This chapter is intended to combine the benefits calculations presented in Chapter 3 and the cost calculations in Chapter 5. To accomplish this task, we use computer software developed for this project, and test the sensitivity of the findings when alternative discount rates and traffic ticket prices are used to examine the streams of benefits and costs over time.

It is worth repeating that on the benefits side, only the tangible benefits discussed in Chapter 3 are used in the calculations in this chapter. Thus, important non-monetary benefits like increased officer safety and productivity continue to be treated qualitatively. In addition, an upper and lower limit was used in calculating the revenue per MRDS arrest for TBW and bylaw warrants; those limits ($30.00 and 25.00 per ticket, respectively) are carried forward into the analysis presented here.

MRDS technology, as implemented in the VPD is expected to have a useful life of ten years, making it appropriate to use a ten year time frame for projecting and then discounting costs and benefits. The expected life span of ten years is contained in some of the City of Vancouver's correspondence on this project. However, because of the unproven nature of the UMCT data terminal, the figure is simply an informed guess. We have not performed the benefit cost calculations on other estimates of the equipment's lifespan because no factual basis exists for choosing a number more or less than ten years, and the extra insights gained are small relative to the extra complications introduced. Benefits from the first four full years of MRDS usage have been projected another five years by taking the average of the TBW and bylaw-related benefits (1981 to 1984) and extrapolating them.

The labor cost savings estimated in the 1979 City Manager's report have been treated as a constant and projected to 1989. Start up costs occur at the beginning of the project, leaving maintenance costs to be extrapolated to 1989. A sensitivity analysis on the anticipated $99,000 dispatcher cost savings is not presented in this Report. The rationale is similar to that given with respect to the 10 year equipment life span. There is no a priori reason to expect the estimate to be biased, and the extra complications outweight the extra insights gained.

6.2 Net Benefits and Benefit-Cost Ratios

Table 6.1 presents the results of benefit-cost calculations using three alternative discount rates (5, 10 and 15 percent) and the two alternative assumptions about revenue from TBW and Bylaw warrant arrests. The important findings from the Table are that under all conditions, MRDS yields positive net benefits and benefit-cost ratios greater than one. As might be expected, the net benefits decrease as the discount rate is increased. Because the stream of benefits is relatively constant over the ten year life of the system, and the bulk of the costs occurs at the beginning of the time period, higher discount rates will tend to reduce the projected benefits in relation to costs.

Selecting a "proper" discount rate for a more precise picture of the yield from this project is not a sensitive issue given the positive picture under a broad range of conditions. At one extreme (15%), MRDS benefits and costs are being discounted rapidly. This rate might be viewed as consisting of a real discount rate of 10% and an additional 5% for inflation. A discount rate of 5%, on the other hand, is generally viewed as being too low to be realistic (Treasury Board of Canada, 1976). Thus, the middle value (10%) is often selected as a rate that realistically brings the cost and benefit streams to present values. If 10% is selected as the "optimal" rate, then even the more conservative scenario presented

in Table 6.1 yields a net benefit of $174,926 and a benefit-cost ratio of 1.196.

A pictorial representation of how net present value varies with different discount rates is presented in Figure 6.1. The important point to note is that net present value remains positive - even in the worst case senario of $25 per ticket - for discount rates up to and including 16%. Needless-to-say this very high rate at which future benefits are discounted is quite unrealistic, yet the MRD System continues to show a positive net payback.

Figures 6.2, 6.3 and 6.4 show a different pictorial method of arranging the same raw data. In these diagrams, net present value is shown as a function of time for three different discount rates (5%, 10%, 15%), and two different ticket prices ($25 and $30). In all cases, the net present value of the technology becomes more rapidly positive at $30 per ticket than at $25 per ticket. This result, of course, is expected because it implies a larger stream of project benefits. As the discount rate rises from 5% to 15%, the Figures 6.2 through 6.4 show that the net present value lines become flatter. Thus, as the discount factor rises, the point at which positive net benefits occur is pushed forward in time. This too is an expected result, but the pictures help the reader to visualize.

FIGURE 6.1

NET PRESENT VALUES VS. DISCOUNT RATES

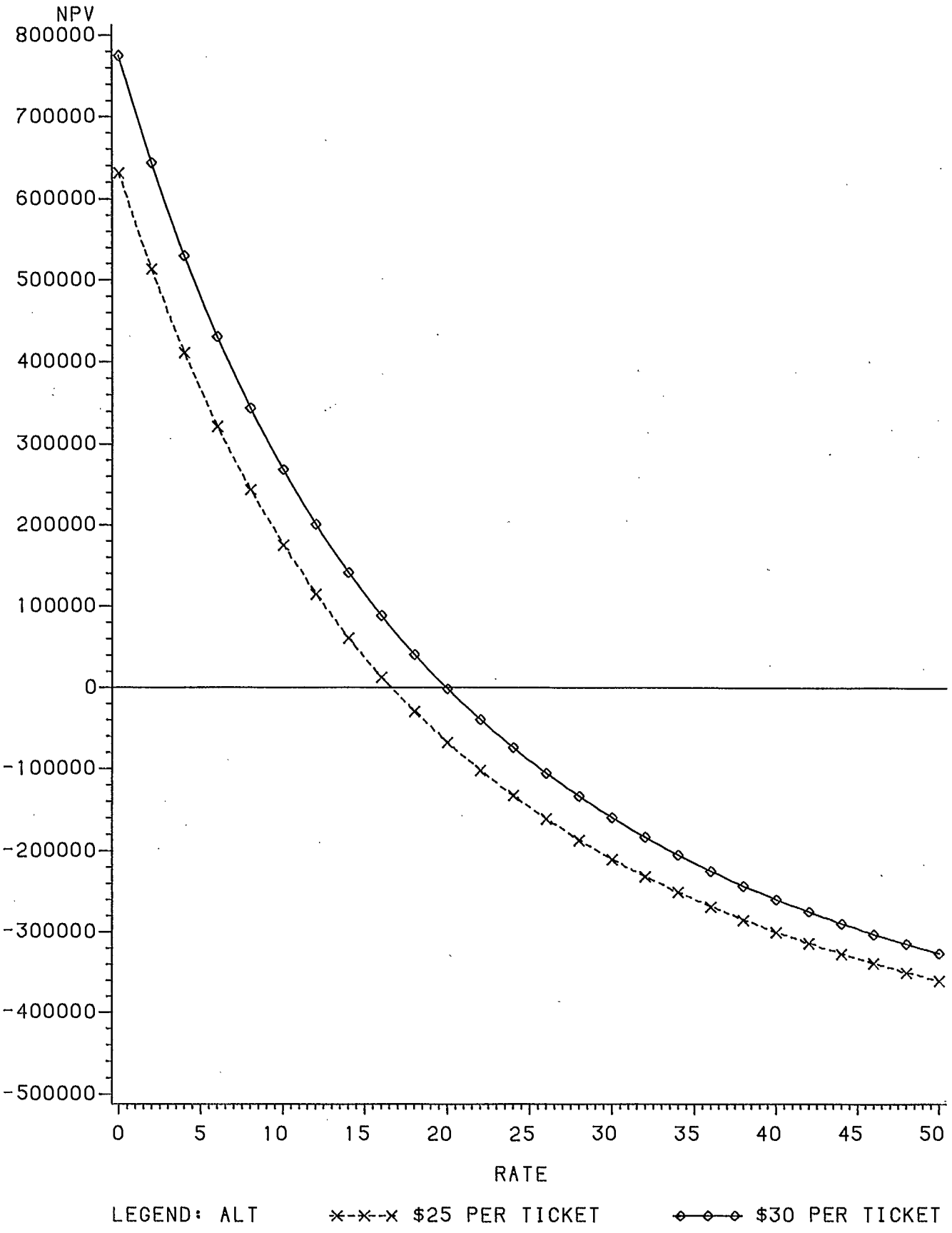


FIGURE 6.2

NET PRESENT VALUES OVER TIME
DISCOUNTED AT 5 PERCENT

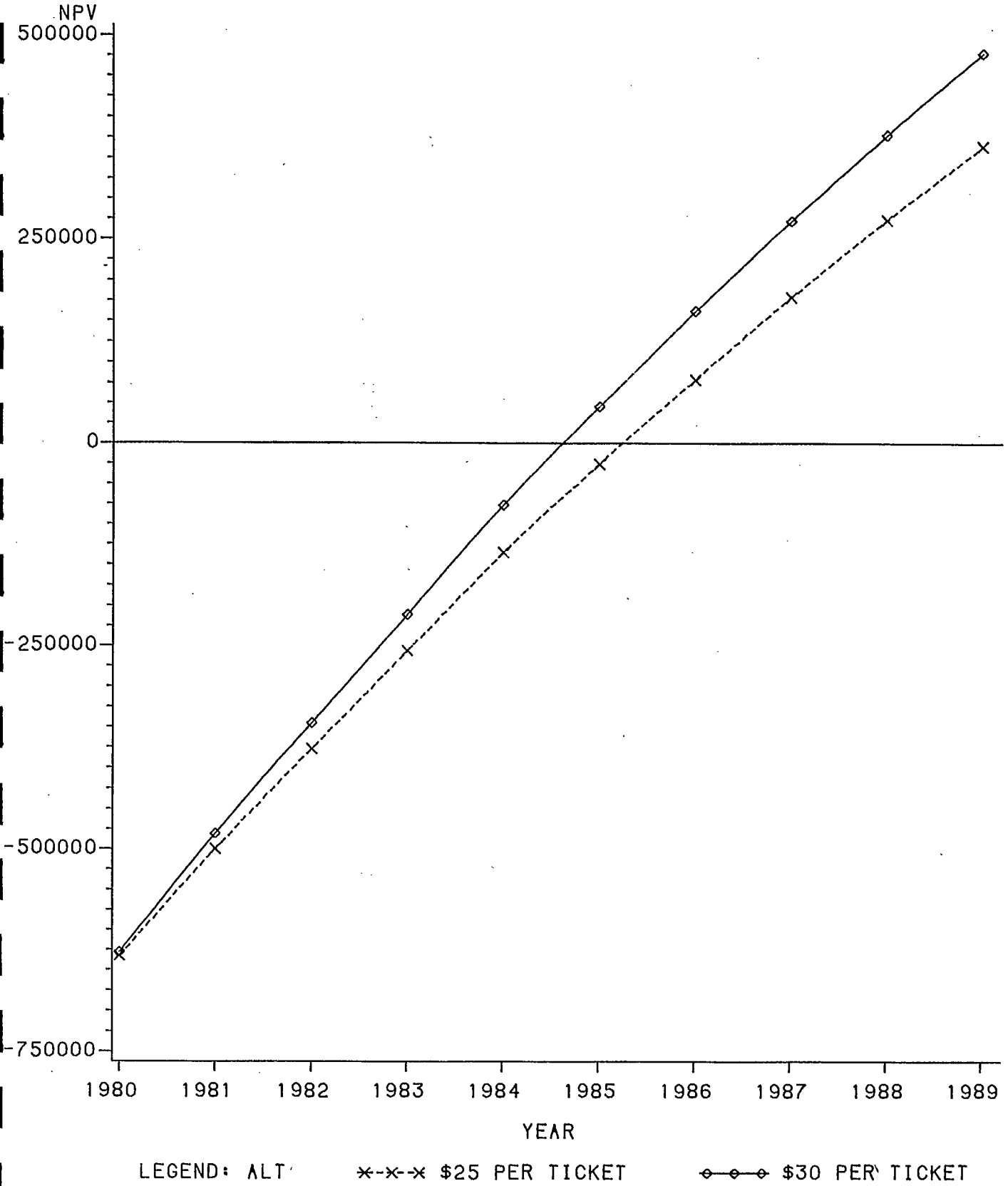


FIGURE 6.3

NET PRESENT VALUES OVER TIME
DISCOUNTED AT 10 PERCENT

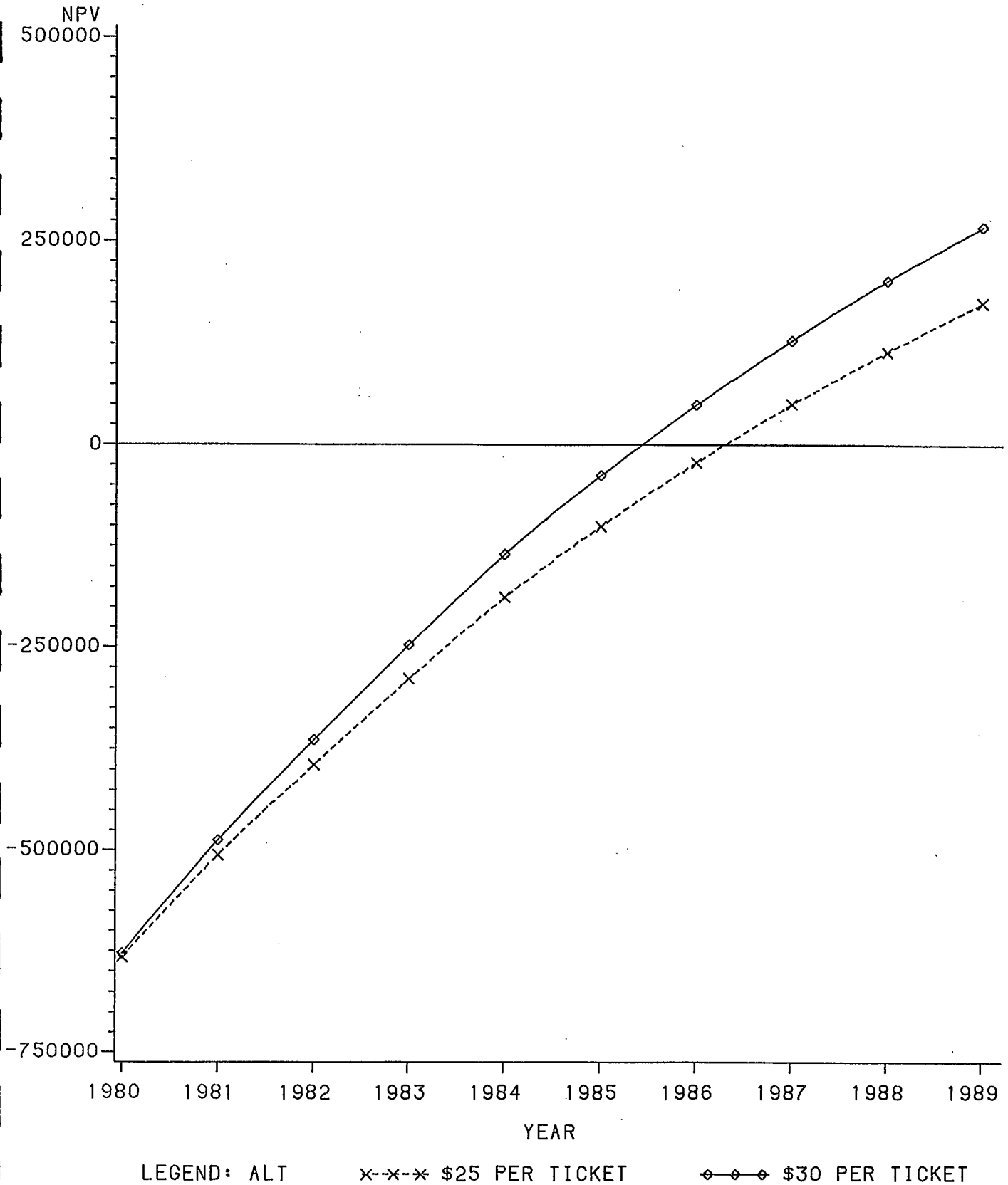
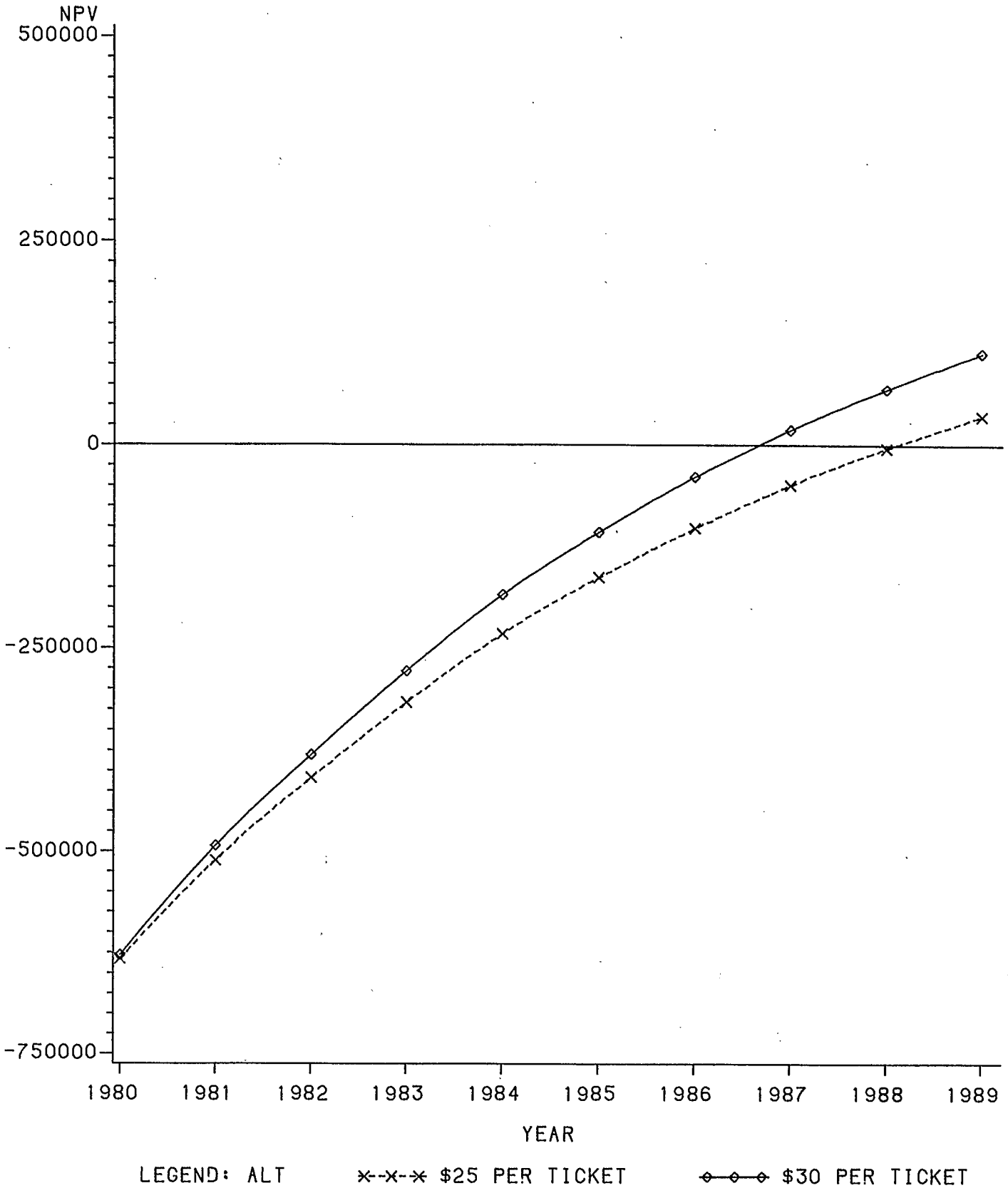


FIGURE 6.4

NET PRESENT VALUES OVER TIME
DISCOUNTED AT 15 PERCENT



Yet a third way to arrange the same raw data is presented in Figures 6.5 through 6.7. These pictures show how the benefit-cost ratios increase as time passes. Again three discount rates, and two ticket prices are used. The benefit-cost figures reported in Table 6.1 are the ratios obtained at the end of the anticipated 10 year equipment life span. The figures simply show the benefit-cost ratio for various years up to and including the final year of the equipment's expected life. As can be seen from these pictures, the benefit-cost ratio rises more rapidly at low discount rates, and at the higher value placed on tickets.

FIGURE 6.5

BENEFIT–COST RATIOS OVER TIME
DISCOUNTED AT 5 PERCENT

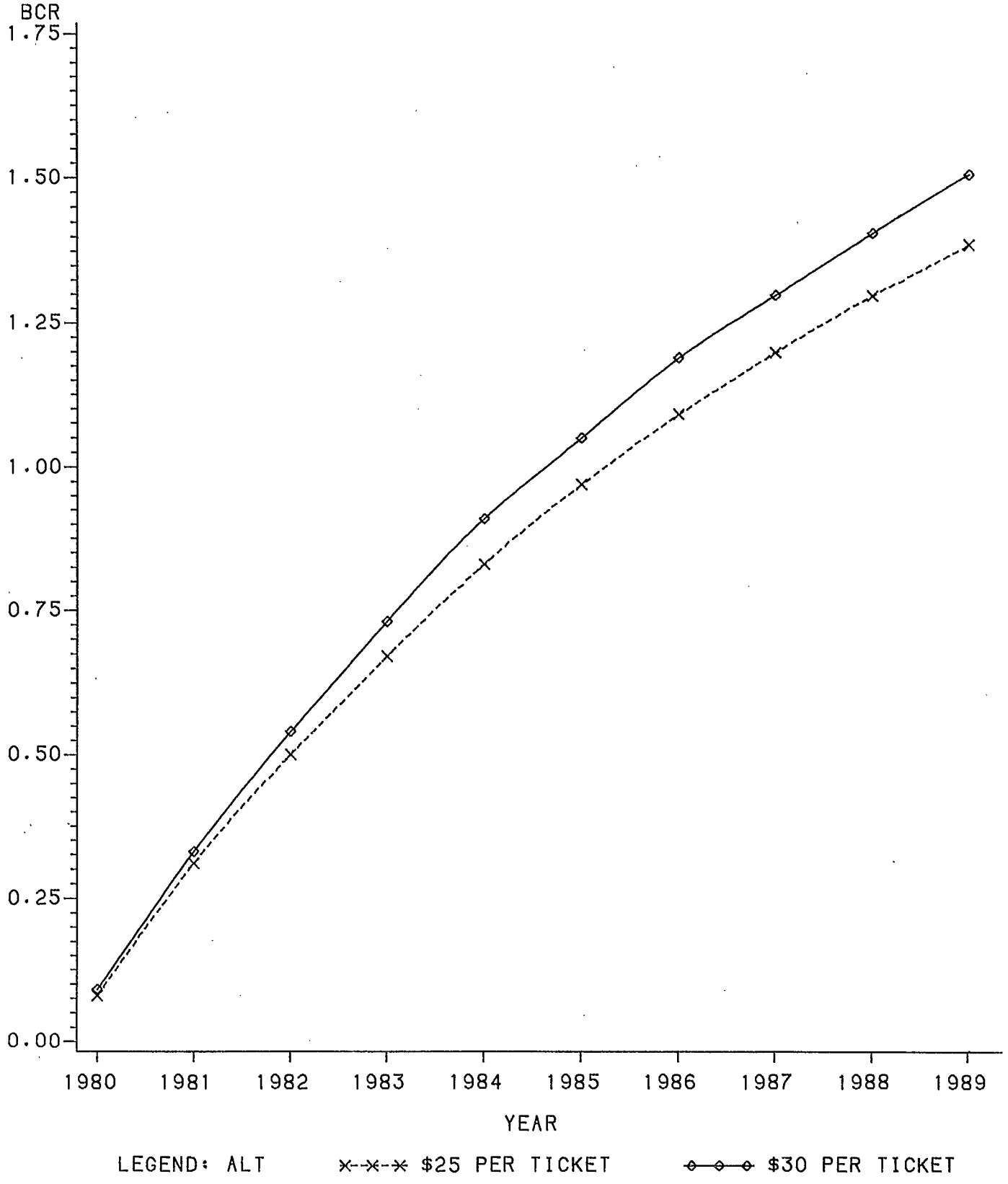


FIGURE 6.6

BENEFIT–COST RATIOS OVER TIME
DISCOUNTED AT 10 PERCENT

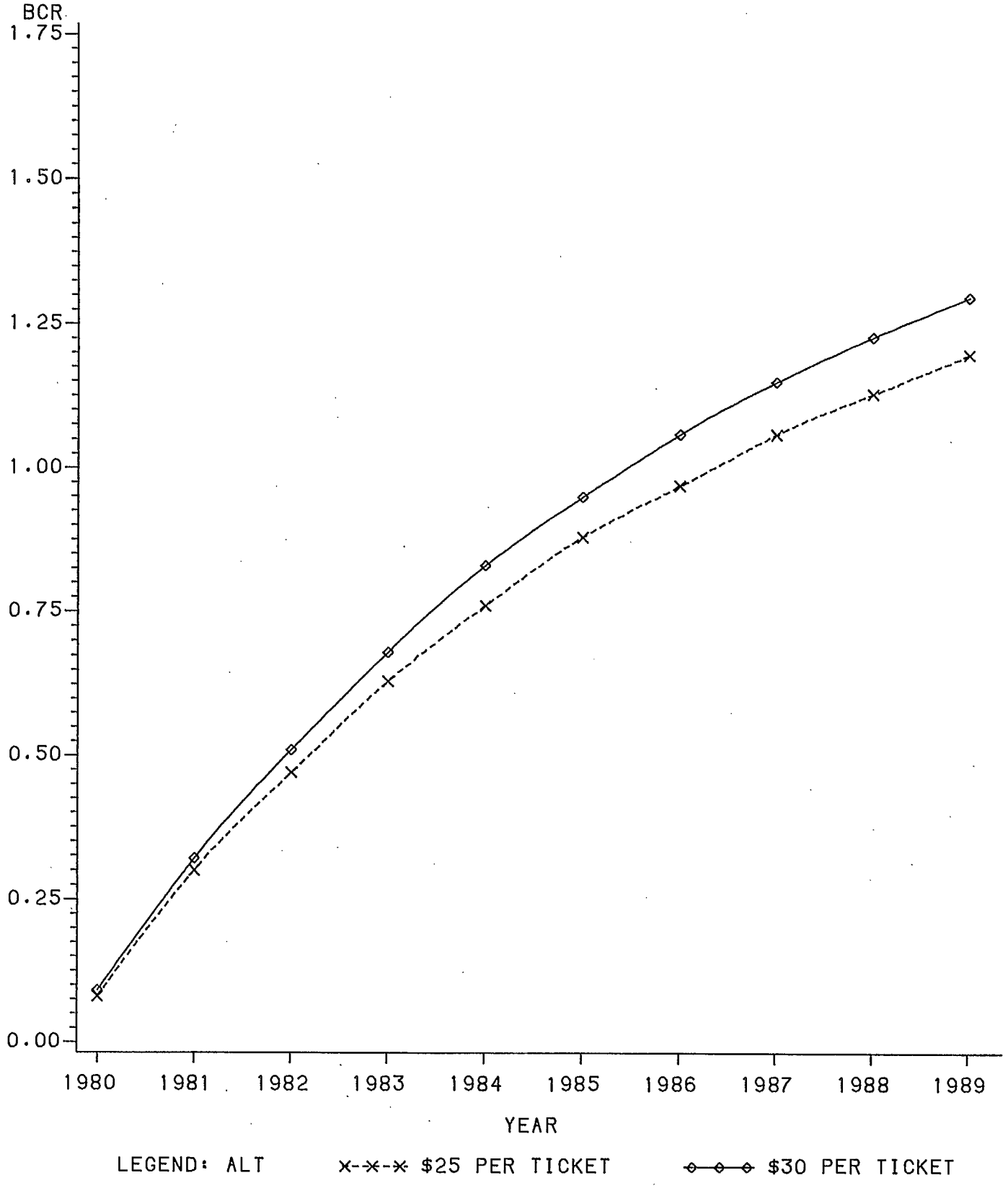


FIGURE 6.7

BENEFIT–COST RATIOS OVER TIME
DISCOUNTED AT 15 PERCENT

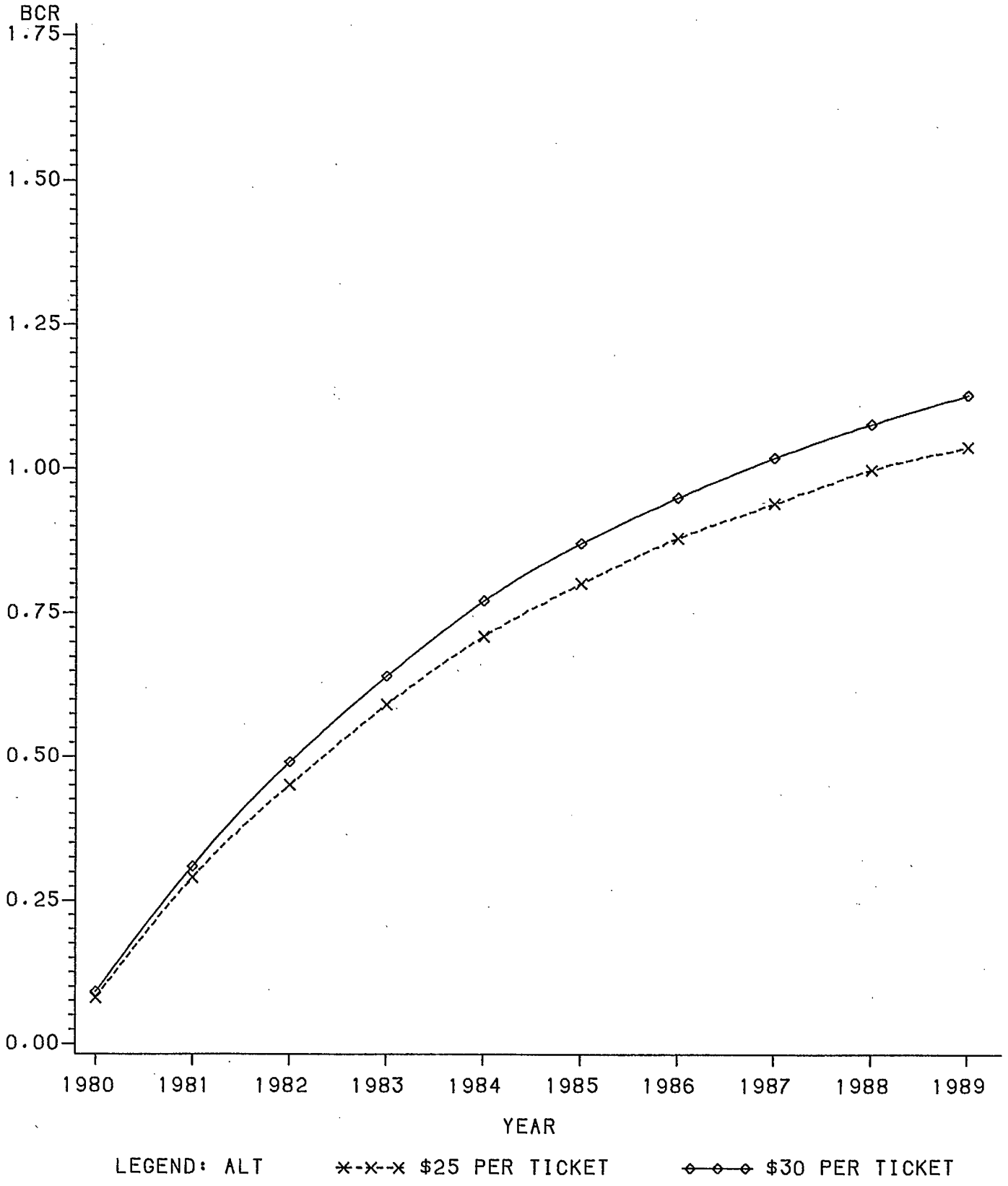


TABLE 6.1

Discounted Benefits and Costs for MRDS System
Over a Ten Year Period

Alternative Discount Rates

Alternative Assumptions About the Benefit Streams	5 Percent		10 Percent		15 Percent	
	Net Present Benefit	Benefit-Cost Ratio	Net Present Benefit	Benefit-Cost Ratio	Net Present Benefit	Benefit-Cost Ratio
Benefits Calculated Assuming $25.00 Revenue Per MRDS Arrest	$ 364,776	1.387	$ 174,926	1.196	$ 46,136	1.054
Benefits Calculated Assuming $30.00 Revenue Per MRDS Arrest	$ 478,914	1.508	$ 268,138	1.300	$ 124,032	1.146

6.3 The Break-Even Points

A complementary way of presenting the benefit-cost findings is displayed in Table 6.2. Break-even points have been calculated using the software developed for this study, and can be seen visually in Figures 6.2 through 6.4 as the point at which the net present value line crosses the horizontal axis. As expected, the break-even points vary with the assumptions made. The most conservative scenario ($25.00 per MRDS arrest and a 15% discount rate) puts the break-even point at the end of the useful life of MRDS. Other scenarios (arguably more realistic ones) move that point closer to the present.

TABLE 6.2

Break-Even Points for MRDS
Under Different Benefit and Discounting Assumptions

Alternative Assumptions About the Benefits	Discount Rates		
	5 percent	10 percent	15 percent
$25.00 Revenue per MRDS Arrest	7 (1986)*	8 (1987)	10 (1989)
$30.00 Revenue per MRDS Arrest	6 (1985)	7 (1986)	8 (1987)

*This is the year in which MRDS is projected to break even under varying conditions.

6.4 Internal Rates of Return

A final way of presenting the findings is to compute an internal rate of return (IRR) that would equate the discounted benefits and costs. In effect, this rate becomes the maximum value of the discount rate that yields a break-even outcome over the ten years of the project.

Calculations based on the $25.00 per ticket assumption yield an IRR of 16.57 percent. If the revenue yield per MRDS arrest is increased to $30.00, the IRR increases to 19.91 percent. These values can be read from Figure 6.1 as the point at which the net present value line crosses the horizontal axis. Both of these discount rates are very high - well beyond any practical discount rate that would be applied to the project, and simply reinforce the findings presented in Tables 6.1 and 6.2.

6.5 Benefit and Cost Profiles

Figures 6.8 to 6.13 show the profile of discounted benefits and costs with respect to time for 3 discount rates and 2 ticket prices. These diagrams show visually the rate at which discounted benefits catch up to, and finally overtake, discounted costs. The point at which the two lines cross is the break-even point at which net present value is equal to zero. These are the same points

FIGURE 6.8

TOTAL COSTS VS. TOTAL BENEFITS
FOR $25 TICKET PRICE
DISCOUNTED AT 5 PERCENT

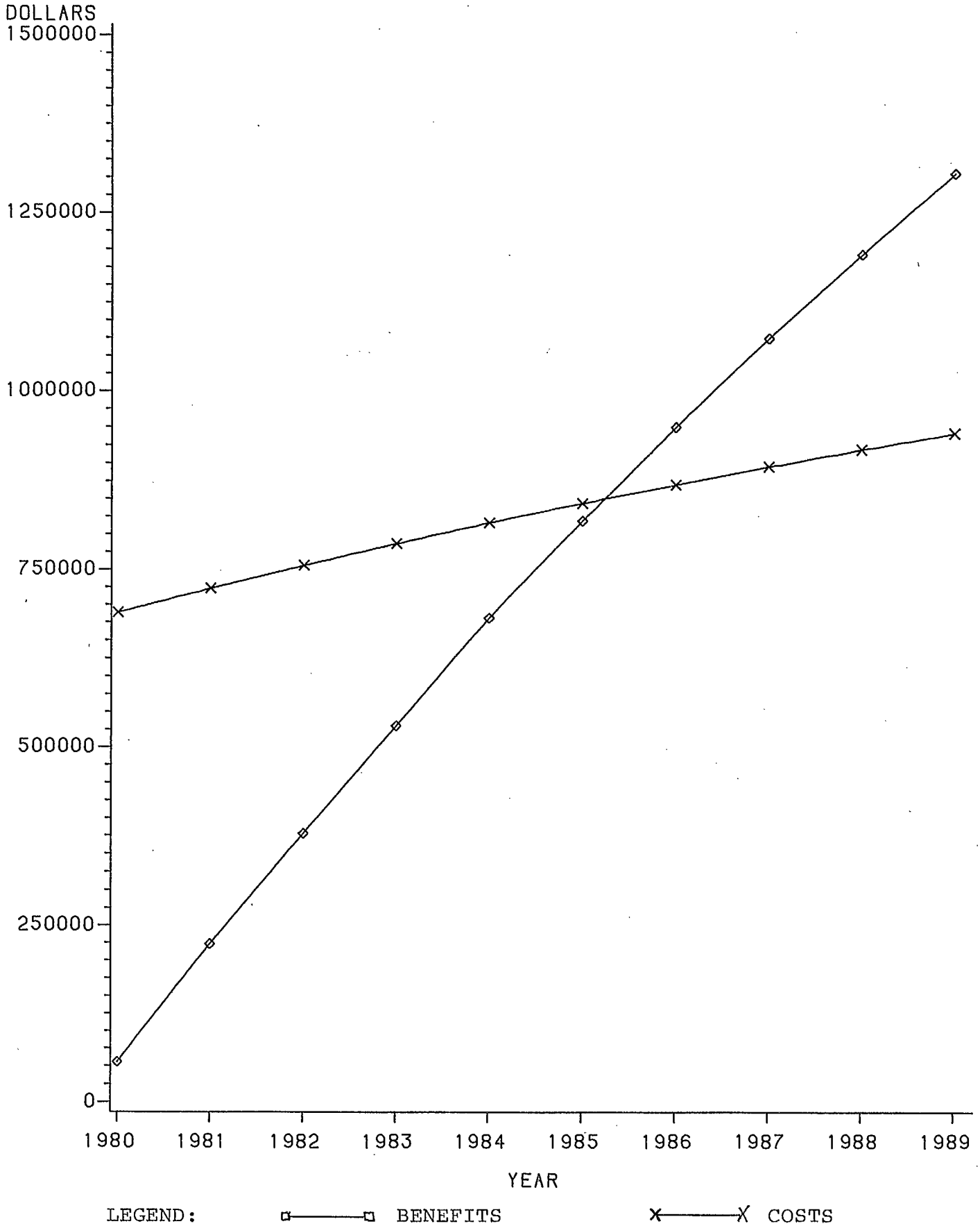


FIGURE 6.9

TOTAL COSTS VS. TOTAL BENEFITS
FOR $25 TICKET PRICE
DISCOUNTED AT 10 PERCENT

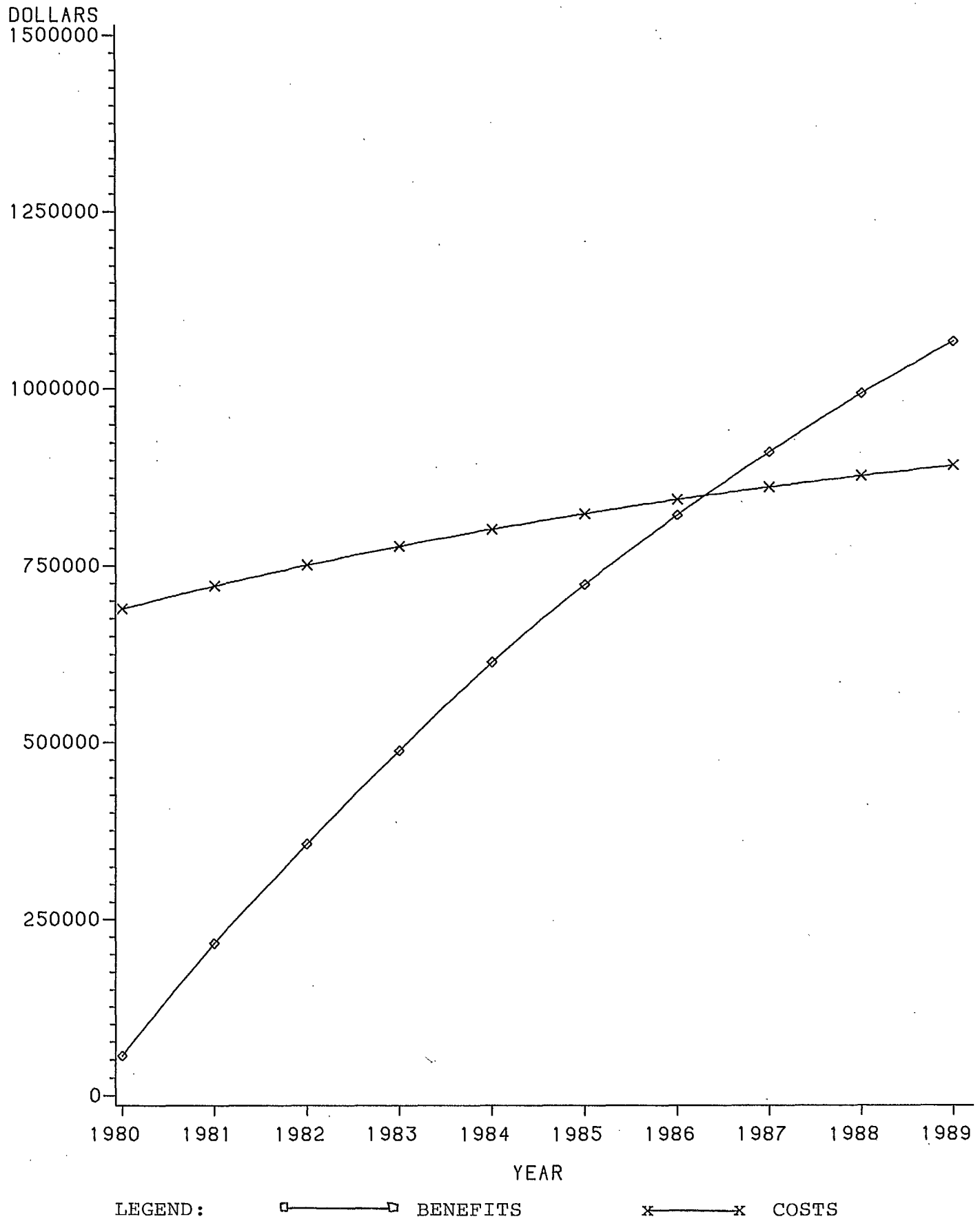


FIGURE 6.10

TOTAL COSTS VS. TOTAL BENEFITS
FOR $25 TICKET PRICE
DISCOUNTED AT 15 PERCENT

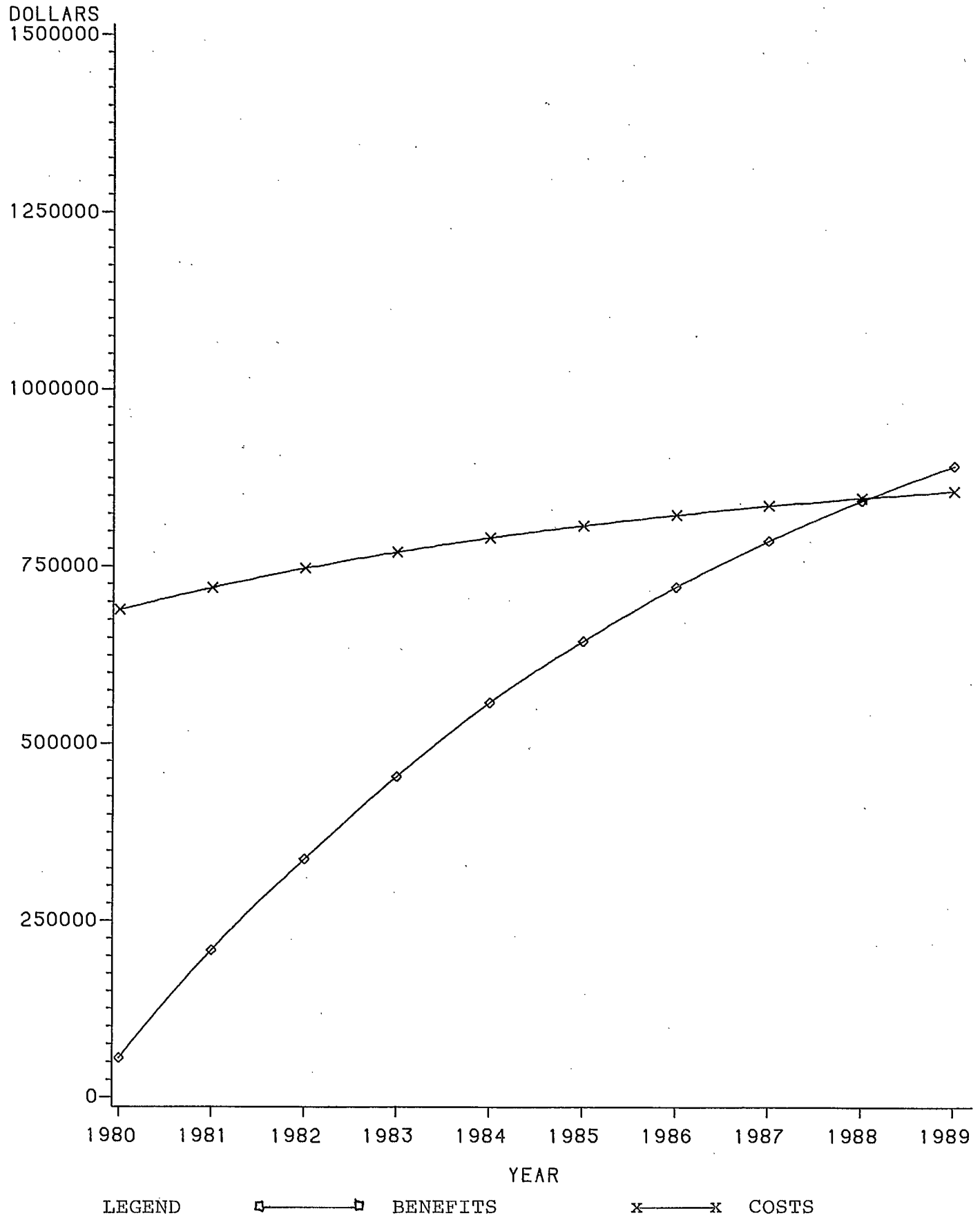


FIGURE 6.11

TOTAL COSTS VS. TOTAL BENEFITS
FOR $30 TICKET PRICE
DISCOUNTED AT 5 PERCENT

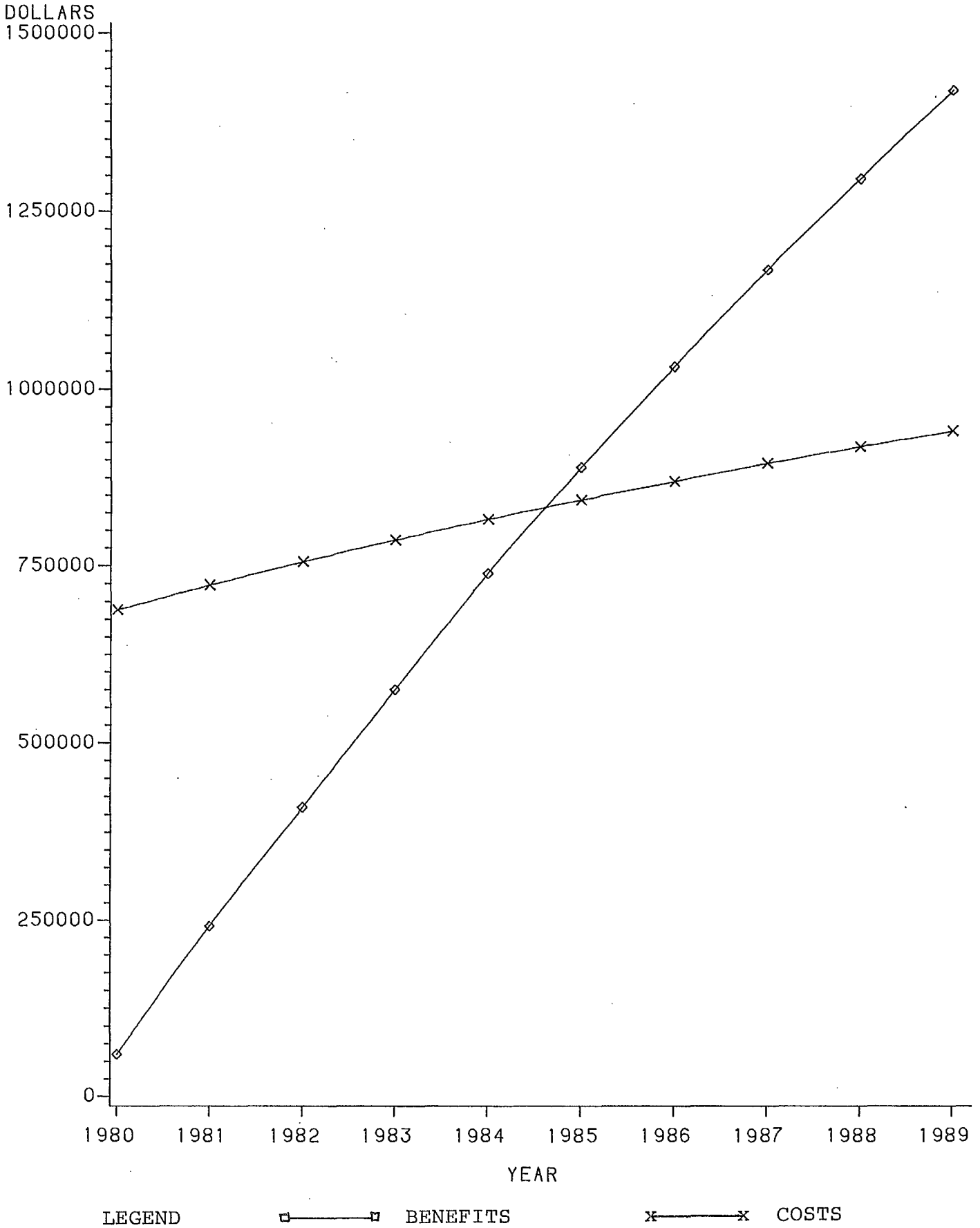


FIGURE 6.12

TOTAL COSTS VS. TOTAL BENEFITS
FOR $30 TICKET PRICE
DISCOUNTED AT 10 PERCENT

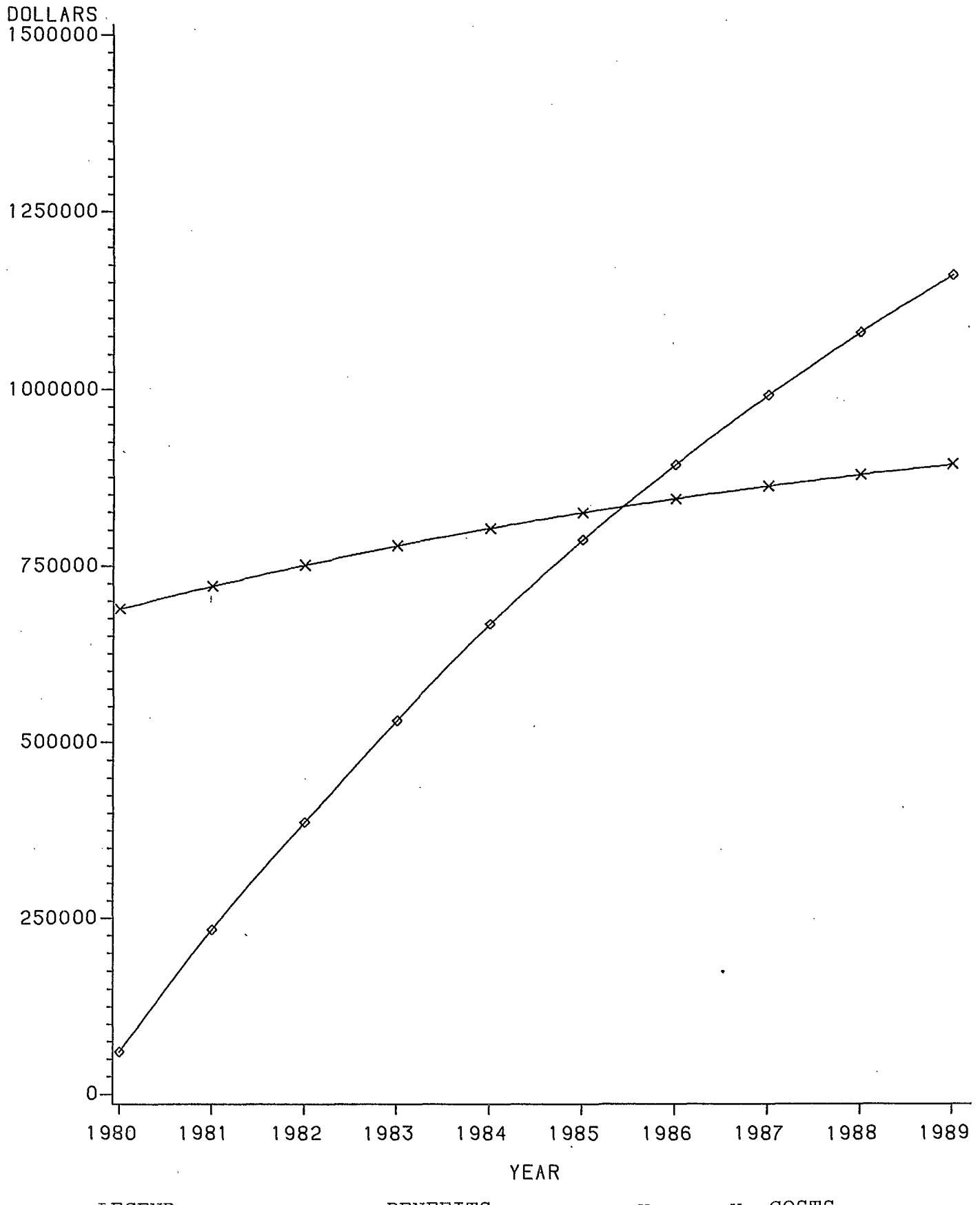
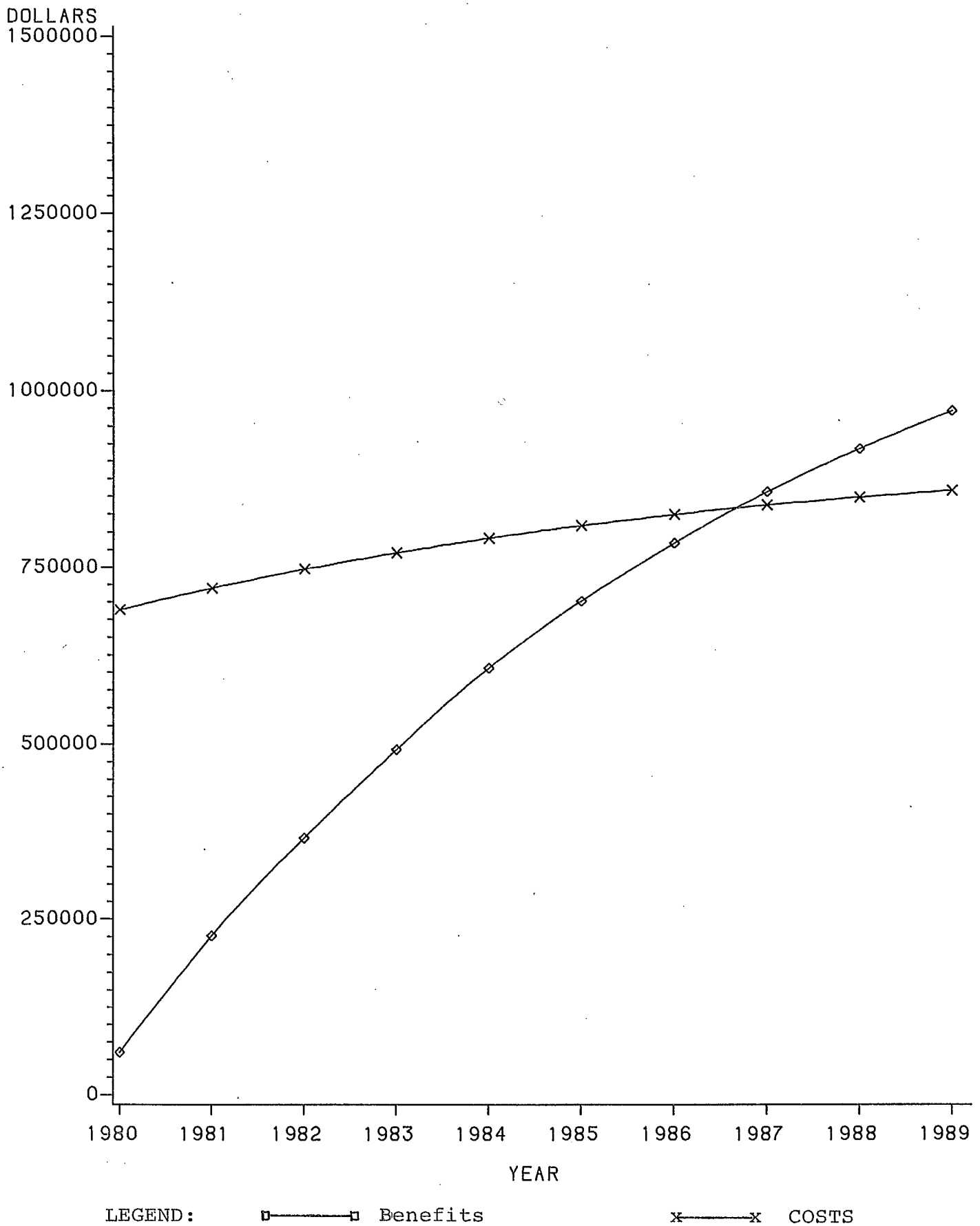


FIGURE 6.13

TOTAL COSTS VS. TOTAL BENEFITS
FOR $30 TICKET PRICE
DISCOUNTED AT 15 PERCENT



identified in Table 6.2, and seen visually in Figures 6.2 through 6.4. The great advantage of the presentation of benefit and cost profiles over time is that one can immediately see the rate at which discounted benefits overtake costs for each assumed ticket price, and how the rate of approach is slowed as the discount rate rises.

6.6 Summary

The findings from this study point strongly to the fact that MRDS is cost-beneficial. Over the projected ten year life of the system, it can easily pay for itself and yield a positive net return on the investment. This conclusion is strengthened further by consideration of important, but intangible benefits from MRDS, which have not been included in the calculations. Officer safety is perceived to be positively affected by MRDS. The information available to police patrolmen via the system can be viewed as an added margin of safety when they are preparing to stop a vehicle. MRDS is also used and cited as a generator of criminal arrests. Thus, the system can be viewed as enhancing the productivity of police officers making criminal arrests when they have access to it.

Overall, MRDS has combined technical expertise from the public and private sectors in Canada to generate a system which is viewed very positively by its users, and can be shown to be an efficient

use of resources. After beginning with hardware manufactured in the United States, the MRDS project has been able to take advantage of much more reliable terminals manufactured in Greater Vancouver. The result has been the implementation of a system which is not only viewed positively by its users, but has generated a demand for the hardware manufactured for MRD transmissions, in other municipal police, taxi and fire departments across North America. Thus, aside from the benefits realized as a result of the VPD having MRDS, there are benefits of a more general sort to the manufacturer and the regional economy from having initiated this project. These "downstream" benefits have not been factored into the analysis of the benefits and costs of this particular project.

With respect to the secondary objective of investigating the feasibility of applying the MRD technology to other communications systems, little can be stated. It is pointed out in Section 5.2.1 of Chapter 5 that other applications of digital transmission capacity will require specialist development costs over-and-above the work already done by the Department of Communications (Ottawa). Any addition of other PCC technologies, especially a CAD system, can be appended to the existing technology used by the VPD, but will also require specialist development costs.

BIBLIOGRAPHY

1. Berreuta-Clement, John R., et al, Changed Lives: The Effects of the Perry Preschool Program on Youths Through Age 19 (Ypsilanti, Michigan: Hi-Scope Press, 1984).

2. Cantel Engineering Associates Ltd., Traffic and Spectrum Use Study of Vancouver Police Department Mobile Radio Data System (MRDS), Vancouver, British Columbia: September 1982.

3. City of Vancouver, City Manager's Report, May 11, 1979.

4. City of Vancouver, Police Communications Centre: Proposal, Vancouver, British Columbia: June 1974. Referenced as the Study Group Report.

5. Colton, K.W., Margret L. Brandeau, and James M. Tien, A National Assessment of Police Command, Control and Communications Systems, Washington, D.C.: National Institute of Justice, January 1983.

6. Cook, Thomas D. and Donald T. Campbell, Quasi Experimentation: Design and Analysis Issues for Field Settings, Chicago: Rand McNally Publishing Co., 1979.

7. Gramlich, Edward M., Benefit-Cost Analysis of Government Programs, Englewood Cliffs, N.J.: Prentice-Hall, Inc. 1981.

8. McRae, J.J., Evaluability Assessment Report on the Vancouver Police Department's Mobile Radio Data System, Victoria, B.C.: Centre for Public Sector Studies, January 1984.

9. Palys, T.S., E.O. Boyanowsky, and D.G. Dutton, A Behavioural Evaluation of the Vancouver Police Department's Mobile Radio Data System, Burnaby, B.C.: Criminology Research Centre of Simon Fraser University, June 1983.

10. Sohn, R.L., et al, Application of Mobile Digital Communications in Law Enforcement - An Introductory Planning Guide, Pasadena, Ca: Jet Propulsion Laboratory, May 1975.

11. Stewart, R.J., MRDS Evaluation, Vancouver Police Department Internal Memo to Spector J.L. Crich, October 1982.

12. Thompson, Mark S., Benefit-Cost Analysis for Program Evaluations, Beverly Hills, Ca.: Sage Publications, 1980.

13. Treasury Board Secretariat, Benefit-Cost Analysis Guide, Ottawa, Ontario, 1976.

14. Urban Sciences Inc., A Study of Digital Communications Equipment for Law Enforcement Use, Wellesley, MA: October 1973.

APPENDIX A

ADDITIONAL STATISTICAL TABLES

TABLE A.2

Criminal Arrests Recorded by the MRDS Survey

	Frequency		Frequency
Second Degree Murder	2	Breach of Bail	18
Sexual Assault	2	Criminal Mischief	14
Rape	1	Impaired Driving	29
Aggrevated Assault	2	Driving Over 80 MGs	7
Assault	32	Prohibited Driver	2
Threatened Assault	1	Obstructing an Officer	3
Assault With Weapon	2	Escape Custody	7
Robbery	17	Suspension of Parole	7
Breaking and Entering	25	Possession for Trafficking	11
Attempted B and E	8	Narcotics in Possession	17
Auto Theft	2	Trafficking	2
Theft Over $200	15	Material Witness	1
Theft Under $200	59	Kidnapping	1
Possession of Stolen Property Over $200	4	Liquor Act	1
Possession of Stolen Property Under $200	11	Family Court	2
Fraud	8	Intimidation	1
False pretenses	12	Cruelty	1
Uttering Forged Documents	2	Minor on Licenced Premises	1
Possession of Dangerous Weapons	5	Warrant of Committal	28
Possession of House Breaking Tools	1	Other Charges	8
Breach of Probation	21	Charge Unspecified	106
		TOTAL:	501

TABLE A.3

Numbers of TTI's and Bylaw Informations
1982-1984

	1982		1983		1984	
Month	TTI	Bylaw	TTI	Bylaw	TTI	Bylaw
September	4496	5157	4166	2349	4108	10949
October	4686	5500	5481	2726	6011	12053
November	4833	6684	5878	2275	4784	11718
December	4746	6128	4622	2880	3384	not available
Yearly Total	54244	59625	57524	23326	60431	78264

APPENDIX B

SURVEY FORM USED TO ASSESS MRDS USAGE

B.F. date _____ P.C. name _____

Team _____

Name of accused _____

Date _____

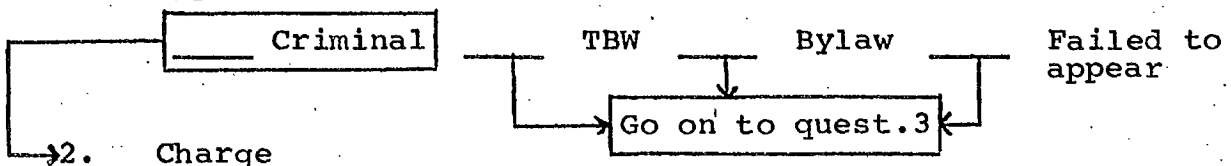
.....

Complete the questionnaire and return it by the above B.F. date to:.

S/Sgt. L.E. Richardson
Aide to D/C/C
Bureau of Support Services

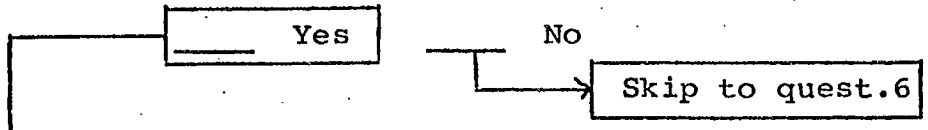
This form focuses on warrant arrests, and is part of an assessment of the Mobile Radio Data System (MRDS).

1. Type of arrest

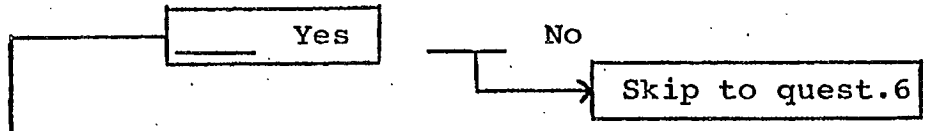


2. Charge _____

3. Was the patrol unit you were operating at the time of the arrest equipped with an MRDS unit?



4. Did you use your vehicle's MRDS unit in connection with making this arrest?



5. In your judgement, was this arrest made as a result of your using your MRDS unit?

____ Yes ____ No

6. During the years you have operated patrol units in the V.P.D., have you had experience in vehicles that did and did not have MRDS units?

____ Experience with both types of patrol vehicles

____ Experience with MRDS equipped units only

____ Experience with non MRDS equipped units only

APPENDIX C

DETAILED BREAKDOWN OF SYSTEM COSTS

COST ITEM 1: COMMUNICATIONS CENTRE EQUIPMENT

1.1 DEC Computer Equipment

Item	Qty.	Feature	Description	
1	2	11/34A-LH	DEC CPU 14KB MOS memory	
	8	MS11-JP	Additional 32KB MOS memory	
		M7850	Parity Control	
		KY11-LB	Programmer's console	
		H960-CA	Cabinet	
		H775-CA	Battery backup	
		DZ11-E	16 line asynchronous mpx.	
		DL11-WB	EIA asynchronous line	
	4	DD11-DK	2 SU Expansion modules	
	2	BA11-KE	10" Expansion chassis	
			Total 11/34	
2	2	LA36-CE	DEC printer 30 cps	
		LAXX-KG	EIA interface	
		LAXX-NE	Print window	
			Total LA36	
3	2	LA180-EA	DEC printer 180 cps	
		LAXX-NE	Print window	
			Total LA180	
4	2	RX11-BA	Diskette control & storage 512KB	
5	2	TMB11-MA	Mag tape storage 800/12.5/600ft.	
6	1	H961-AA	Cabinet for switches & modems	
7	1	QJ642-AD	RSX-11SV2 Operating System	
	1	QJ003-AY	RT-11 QV2C Operating System	
	1	QJ925-AY	FORTRAN IV/RT11 VOIC	
8	1	RK11J-DE	Disk control and drive 2.5MB	
	1	RK05EFA	Disk Drive 5MB	
	10	RK05	Disk Cartridge	
			Total DEC Computer Equipment	$ 146 953
			Less Federal Test Bed Allowance	- 50 000
			NET DEC Computer Equipment	$ 96 953

1.2 MDA-Supplied Equipment

Item	Qty.	Feature	Description
1	2	CC48001	CC/radio channel interface
2	1	154-005-16	T-Bar switch 16 channel
3	2	10120D	Ontel CRT 32KB memory
4	1		EIA RS232 cables (see Site Analysis Report)
	20		3 ft. length
	5		160 ft. length
5			Computer supplies
	10		Floppy diskettes
	10		Magnetic tape reels
	1 box		Printer ribbon LA36
	1 box		Printer ribbon LA180
	4 boxes		Printer paper
			Total supplies
6	2		Elapsed timer meters
7	1		MDA proprietary software
8	1		MRDS IIA Software
			Total MDA Equipment $ 42 943

COST ITEM 2: DIGITAL RADIO EQUIPMENT

2.1 Public Safety Building (Main St.)

Item	Qty.	Feature	Description	Price
1	1	MICOR	Base radio c/w cabinet	$ 4 560
2	1	TMN 6071	Test microphone	53
3	1	DC 4801	MDA base interface	3 749
4	1	P2B03G	Duplexer	752
5	2	1-150-1R7	Reject cavity - digital	406
6	1	1-150-1R10	Reject cavity - voice voter	323
7	1	212-EB	Antenna, mast and mount/hw	267
8	1		Antenna Tx line and i/c cables	382
9	1	1-8D-204	12V battery backup and tray	245
			Total Main Street Sites	$ 10 737

2.2 Grouse Mountain Site

Item	Qty.	Feature	Description	Price
1	2	MIOR	Base radio c/w cabinet	$ 9 120
2	1	TMN6071	Test microphone	53
3	1	DC4801	MDA base interface	3 749
4	1	C357SP	0.5 mHz Multicoupler	1 406
5	1	CR2-2C03DF	2 Rx Multicoupler	465
6	4	2-150-2S7-SP	Band pass cavity w/phasing harness	788
7	2	H360-150	Ferrite isolators w/mount	753
8	1	210-C4	Antenna w/9° electric tilt	736
9	1 set		Antenna Tx cables w/hardware	423
10	1	1-8D-204	12V battery backup and tray	245
			Total Grouse Mountain Site	$ 17 738

COST ITEM 3: MOBILE DATA TERMINALS AND RADIOS

Item	Qty.	Feature	Description	Price
1	12	D119A	Motorola multi-line MDT	$ 61 380
		--	Mounting trunion	incl.
		J153AA	Memory expansion	incl.
		MDA	High speed modem	incl.
			Total MDT	$ 61 380
2	12	MOCOM 70	Mobile radio w/antenna incl. MDA modification	15 600
			Total MDT and Radio	$ 76 980

COST ITEM 4: INSTALLATION

4.1 Communication Centre Installation

Installation, alignment and check out of all computer equipment, data terminals and interconnection cables will be performed as described in the Site Analysis Report produced by MDA under the Federal Contract.

The charges for this installation are:

1. MDA effort to plan, disassemble, install, check out and supervise installation:

Level	Mandays	Price
Senior	20	$ 7 620
Intermediate	10	2 880
Technicians	2	326
Total		$ 10 826

2. Subcontractor charges to disassemble, move and install equipment:

$ 2 946

Total Communication Centre Equipment $ 13 772

4.2 Digital Radio Channel Information ... Cont'd

The charges for the installation are:

1. MDA effort to supervise, install, check out and optimize equipment.

Level	Mandays	Price
Senior	19	$ 7 239
Intermediate	7	2 016
Junior	7	1 505
Technicians	3	489
Total		$ 11 249

2. Subcontractor charges (Motorola) $ 2 071

3. Expenses $ 800

Total Radio Channel Installation $ 14 120

4.3 Mobile Terminal Installation

Mobile terminals and radios will be installed by MDA or its authorized subcontractor on 3 police vehicles. The City shall be notified in order to witness the installation.

MDA staff will be available to advise on installation of remaining 8 mobile terminal systems.

The charges for this installation are:

1. MDA effort:

Level	Mandays	Price
Intermediate	3	$ 864
Junior	1	215
Total Effort		$ 1 079
2. Subcontractor charges		$ 390
Total MDT Installation		$ 1 469

COST ITEM 5: OTHER CHARGES

5.1 Miscellaneous Charges

a.	Supervision During Agency 'Hardware' Conformance Tests	Per Diem as set out previously
b.	Documentation reproduction of M.R.D.S. IIA documents	$3 000
	Total Miscellaneous Charges	$ 3 000

5.2 Optional Equipment and Services

Telephone System Microprocessor Attachment

The telephone microprocessor system generates usful statistics on 911 call activity and response time. We concur that its direct attachment to the MRDS computers would simplify and consolidate data gathering to one system and thus enhance the performance measurement and reporting for the police communications complex. As well, direct cost savings would result through displacement of the teletype printers and elimination of keypunching the 911 data.

We recommend that the microprocessor be attached to the asynchronous multiplexer via a standard EIA interface to enable it to be switched in a standard manner from the main to backup system. Furthermore, it should conform to the control and data character set of the DEC LA36 keyboard printer so that by using a standard driver package, memory requirements are minimized. Finally, the data stream from the microprocessor should be in report format with a special character identifying the end of text.

The MDA module would then receive the text and log it directly to the printer and magnetic tape (with a unique record code). The acceptance test for this interface would be to demonstrate tape and printer logging of data entered via a LA36 keyboard. It will be the City's responsibility to adapt and attach the microprocessor.

Level	Mandays	Price
Senior	2	$ 762
Junior	11	2 365
Total		$ 3 127*

* This cost is not included as part of the MRD System costs because it is not directly related to the system.

COST ITEM 6: ADDITIONAL COMMUNICATIONS CENTRE EQUIPMENT

6.1 Outside Supplies

Item	Qty.	Model	Description	Price
1	2	1012D	Ontel OP1/74 Terminals	$ 17 631
			RS Cable	360
2	1	MS11LB	128KB MOS Memory	7 966
			Total:	$ 25 957

COST ITEM 7: MOBILE DATA TERMINALS

Item	Qty.	Model	Description	Price
1	48	UMCT	Mobile Data Terminal at $5 747 each	$ 275 856
2	12	MODAT	Mobile Data Terminal returned to MDA	-
			Total:	$ 275 856

COST ITEM 8: INSTALLATION COSTS

1.	Communication Centre Installation	$ 1 898
2.	Engineering Supervision and Checkout	$ 15 440
	Total:	$ 17 338

APPENDIX D

PROGRAM LISTING OF BENEFIT-COST SOFTWARE

```
$JOB WATFIV
C*****************************************************************
C
C    PROGRAM NAME:   CBA WATFIV
C
C    PURPOSE:        TO PRODUCE THE FOLLOWING TABLES:
C                    (1) COSTS-BENEFITS ANALYSIS
C                    (2) SENSITIVITY ANALYSIS OF DISCOUNT RATES
C
C    PROGRAMMER:     ROBERT LEE
C                    SCHOOL OF PUBLIC ADMINISTRATION
C                    UNIVERSITY OF VICTORIA
C                    P.O. BOX 1700
C                    VICTORIA, B.C.
C                    V8W 2Y2
C
C    DATE CREATED:   MAY 1982
C
C    LAST UPDATED:   APRIL 10, 1985
C
C*****************************************************************
C
C
      DIMENSION COST(5,5,50), BENFIT(5,5,50), DRATE(10), BCRATE(5,50)
      DIMENSION IRR(5), NPV(5,50), RRPV(5)
      DIMENSION SRATE(50)
      COMMON /AREA1/COST, BENFIT
      COMMON /AREA2/NPV, BCRATE, IPROJ, IYEAR, NSRATE, SRATE
      REAL IRR, NPV, LEFT, RIGHT, LPV, RPV
      INTEGER CMAX(5), BMAX(5)
      LOGICAL PRINT, LESS, MORE
      DATA EPS/5E-3/,PRINT/.FALSE./
      READ, NDRATE
      DO 1000 I=1,NDRATE
1000  READ, DRATE(I)
      READ, RATE1,RATE2,INC
      SRATE(1)=RATE1
      NSRATE=1
      WHILE (SRATE(NSRATE).LT.RATE2) DO
         NSRATE=NSRATE+1
         SRATE(NSRATE)=SRATE(NSRATE-1)+INC
      END WHILE
      READ, IPROJ, IYEAR
      DO 1010 ICOMP=1,IPROJ
         READ, K,CMAX(ICOMP),BMAX(ICOMP)
         IF (K.NE.ICOMP) GOTO 9999
         M=CMAX(ICOMP)
         N=BMAX(ICOMP)
         DO 1020 IY=1,IYEAR
            READ, (COST(ICOMP,J,IY),J=1,M),(BENFIT(ICOMP,J,IY),J=1,N)
1020     CONTINUE
1010  CONTINUE
C
C     THIS SEGMENT WILL CALCULATE ALL VALUES FOR THE COSTS-
```

```
C     BENEFITS MATRICES
C
      DO 5000 ICOMP=1,IPROJ
         DO 5010 IRATE=1,NDRATE
            PRINT=.TRUE.
            CALL CALCU(DRATE(IRATE),ICOMP,IYEAR,CMAX(ICOMP),BMAX(ICOMP),
     *                 BCRATE(ICOMP,IRATE),NPV(ICOMP,IRATE),PRINT)
5010     CONTINUE
5000  CONTINUE
C
C     THE FOLLOWING SECTION PERFORMS THE SENSITIVITY ANALYSIS
C     OF DISCOUNT RATES.
C
      DO 6000 ICOMP=1,IPROJ
         IRR(ICOMP)=101.
         LEFT=-1.
         RIGHT=101.
         LPV=1.E20
         RPV=-1.E20
C
C        THE FOLLOWING SEGMENT WILL CALCULATE THE NECESSARY
C        INFORMATION TO FILL THE SENSITIVITY ANALYSIS TABLE.
C        IT WILL ALSO DECIDE THE INTERVALS ON WHICH THE INTERNAL
C        RATES OF RETURNS WILL FALL.
C
         DO 6001 IRATE=1,NSRATE
            CALL CALCU(SRATE(IRATE),ICOMP,IYEAR,CMAX(ICOMP),BMAX(ICOMP),
     *                 BCRATE(ICOMP,IRATE),NPV(ICOMP,IRATE),PRINT)
            IF (IRR(ICOMP).EQ.101.) THEN DO
               LESS=NPV(ICOMP,IRATE).LE.LPV
               MORE=NPV(ICOMP,IRATE).GT.RPV
               IF (LESS.AND.(NPV(ICOMP,IRATE).GT.EPS)) THEN DO
                  LEFT=SRATE(IRATE)
                  LPV=NPV(ICOMP,IRATE)
               ELSE DO
                  IF (MORE.AND.(NPV(ICOMP,IRATE).LT.(-EPS))) THEN DO
                     RIGHT=SRATE(IRATE)
                     RPV=NPV(ICOMP,IRATE)
                  ELSE DO
                     IF (ABS(NPV(ICOMP,IRATE)).LT.EPS)
     *                  IRR(ICOMP)=SRATE(IRATE)
                  END IF
               END IF
            END IF
6001     CONTINUE
C
C        THE FOLLOWING SEGMENT WILL FIND THE INTERNAL RATES OF
C        RETURN BY USING THE BISECTION METHOD (FOR GURANTEED RESULTS).
C        THE TWO INITIAL VALUES ARE DETERMINED BY THE ABOVE ROUTINE.
C
         WHILE (((LEFT*RIGHT).GT.0.).AND.((LPV*RPV).LT.0.).AND.
     *          (IRR(ICOMP).EQ.101.)) DO
            CENTER=(LEFT+RIGHT)/2.
            CALL CALCU(CENTER,ICOMP,IYEAR,CMAX(ICOMP),BMAX(ICOMP),DL,
```

```
     *            PV,PRINT)
                IF ((ABS(PV).LT.EPS).OR.(ABS(LEFT-RIGHT).LT.EPS)) THEN DO
                   IRR(ICOMP)=CENTER
                   RRPV(ICOMP)=PV
                ELSE DO
                   IF ((PV.LT.LPV).AND.(PV.GT.EPS)) THEN DO
                      LEFT=CENTER
                      LPV=PV
                   ELSE DO
                      RIGHT=CENTER
                      RPV=PV
                   END IF
                END IF
             END WHILE
6000  CONTINUE
C
C     THIS ROUTINE WILL TABLULATE THE SENSITIVITY ANALYSIS TABLE
C
      CALL SENSIT
      DO 6011 ICOMP=1,IPROJ
         IF (IRR(ICOMP).NE.101.) THEN DO
            WRITE(12,606) ICOMP,IRR(ICOMP),RRPV(ICOMP)
         ELSE DO
            WRITE(12,603) ICOMP,SRATE(NSRATE)
            LESS=NPV(ICOMP,1)+NPV(ICOMP,NSRATE).LT.0
            IF (LESS) THEN DO
               WRITE(12,605)
            ELSE DO
               WRITE(12,604)
            END IF
         END IF
6011  CONTINUE
      STOP
C
C     FORMATS
C
603   FORMAT('-THE IRR FOR PROJECT',I2,' IS UNDEFINED WITHIN THE 0 AND '
     *,F6.2,'% RANGE')
604   FORMAT(' (POSITIVE NPV WITHIN THE RANGE)')
605   FORMAT(' (NEGATIVE NPV WITHIN THE RANGE)')
606   FORMAT('-THE IRR FOR PROJECT',I2,' IS',F7.2,'% (NPV=',F6.2,')')
999   FORMAT('1','DATA FILE ERROR... JOB ABANDONED')
C
9999  WRITE(12,999)
      STOP
      END
C
C
C     SUBROUTINE CALCU WILL PERFORM THE ACTUAL CALCULATION FOR THE
C     COSTS-BENEFITS MATRICES
C
C
      SUBROUTINE CALCU (R,IPROJ,IYEAR,M,N,BCR,PV,PRINT)
C
```

```
      DIMENSION WC(5,50), WB(5,50), DNET(50), TWC(50)
      DIMENSION TWB(50), IY(50), DF(50), CTWC(50), CTWB(50)
      DIMENSION CDNET(50), CDNETR(50)
      LOGICAL PRINT, FIND
      INTEGER EVENYR
      COMMON /AREA1/COST(5,5,50), BENFIT(5,5,50)
C
      FIND=.FALSE.
      EVENYR=101
      PVC=0.
      PVB=0.
      PV=0.
      FACTOR=1./(1.+R/100.)
      DO 110 I=1,IYEAR
         DNET(I)=0.
         DF(I)=FACTOR**(I-1)
         TWC(I)=0.
         TWB(I)=0.
         DO 120 J=1,M
            WC(J,I)=COST(IPROJ,J,I)*DF(I)
            TWC(I)=TWC(I)+WC(J,I)
            PVC=PVC+TWC(I)
120      CONTINUE
         DO 130 J=1,N
            WB(J,I)=BENFIT(IPROJ,J,I)*DF(I)
            TWB(I)=TWB(I)+WB(J,I)
            PVB=PVB+TWB(I)
130      CONTINUE
         CTWC(I)=PVC
         CTWB(I)=PVB
         CDNET(I)=PVB-PVC
         CDNETR(I)=PVB/PVC
         DNET(I)=TWB(I)-TWC(I)
         IF (I.GT.1) PPV=PV
         PV=PV+DNET(I)
         IF ((I.NE.1).AND.(.NOT.(FIND))) THEN DO
            EVEN=PPV*PV
            IF (EVEN.LE.0) THEN DO
               FIND=.TRUE.
               EVENYR=I
            END IF
         END IF
110   CONTINUE
      BCR=PVB/PVC
      IF (PRINT) THEN DO
         WRITE(12,1010) IPROJ,R
         DO 140 J=1,IYEAR
140      IY(J)=J
         DO 150 I=1,IYEAR,5
            LEN=MIN0(I+4,IYEAR)
            WRITE(12,1020) (IY(J),J=I,LEN)
            WRITE(12,1030) (DF(J),J=I,LEN)
            DO 160 K=1,M
160            WRITE(12,1040) K,(COST(IPROJ,K,J),J=I,LEN)
```

```
            WRITE(12,1050)  (TWC(J),J=I,LEN)
            DO 170 K=1,N
170            WRITE(12,1060) K,(BENFIT(IPROJ,K,J),J=I,LEN)
            WRITE(12,1070)  (TWB(J),J=I,LEN)
            WRITE(12,1080)  (DNET(J),J=I,LEN)
            WRITE(12,1090)
150      CONTINUE
         IF (EVENYR.NE.101) THEN DO
            WRITE(12,1100) EVENYR
         ELSE DO
            WRITE(12,1110)
         END IF
         DO 190 I=1,IYEAR
            WRITE(13,1120) IPROJ,R,I,CDNET(I),CDNETR(I)
            WRITE(11,1120) IPROJ,R,I,CTWC(I),CTWB(I)
190      CONTINUE
         WRITE (12,1130) PV
         WRITE (12,1140) PVC
         WRITE (12,1150) PVB
         WRITE (12,1160) BCR
         PRINT=.FALSE.
      END IF
C
C     FORMATS
C
1010  FORMAT('1','COSTS-BENEFITS MATRIX FOR PROPOSAL ',I2,' (AT',F6.2,'%
     *)',/,1X,49('-'),//)
1020  FORMAT(' YEAR',14X,5(6X,I2,4X),/)
1030  FORMAT(' DISCOUNT FACTORS',2X,5(1X,F11.2),/)
1040  FORMAT(' COST FACTOR',I3,4X,5(1X,F11.2))
1050  FORMAT('-TOTAL WEIGHTED C. ',5(1X,F11.2),//)
1060  FORMAT(' BENEFIT FACTOR',I3,1X,5(1X,F11.2))
1070  FORMAT('-TOTAL WEIGHTED B. ',5(1X,F11.2),//)
1080  FORMAT(' DISCOUNTED NET B. ',5(1X,F11.2),/)
1090  FORMAT(' ',78('-'),//)
1100  FORMAT(' THE PROPOSAL BREAKS EVEN IN YEAR',I3)
1110  FORMAT(' THERE IS NO BREAK EVEN POINT FOR THIS PROPOSAL')
1120  FORMAT(I3,F6.2,I3,2F11.2)
1130  FORMAT(' NET PRESENT VALUE:     ',F11.2)
1140  FORMAT(' PRESENT VALUE COST:    ',F11.2)
1150  FORMAT(' PRESENT VALUE BENEFIT:',F11.2)
1160  FORMAT(' BENEFIT-COST RATIO:    ',F11.2)
      RETURN
      END
C
C
C     SUBROUTINE SENSIT WILL PRINT THE SENSITIVITY ANALYSIS
C     OF DISCOUNT RATE TABLE
C
C
      SUBROUTINE SENSIT
      COMMON /AREA2/NPV(5,50),BCR(5,50),IPROJ,IYR,NSRATE,SRATE(50)
      REAL NPV
C
```

```
      WRITE(12,100)
      WRITE(12,101)
      DO 1000 I=1,NSRATE,5
         LEN=MIN0(I+4,NSRATE)
         WRITE(12,103) (SRATE(JJ),JJ=I,LEN)
         DO 1010 J=1,IPROJ
            WRITE(12,102)
            WRITE(12,104) J, (NPV(J,II),II=I,LEN)
            WRITE(12,105) (BCR(J,II),II=I,LEN)
1010     CONTINUE
         WRITE(12,101)
1000  CONTINUE
      DO 1020 ICOMP=1,IPROJ
         DO 1030 IRATE=1,NSRATE
            WRITE(14,106) ICOMP,SRATE(IRATE),NPV(ICOMP,IRATE)
1030     CONTINUE
1020  CONTINUE
C
100   FORMAT('1','SENSITIVITY ANALYSIS OF DISCOUNT RATES',//)
101   FORMAT(1X,78('*'),/)
102   FORMAT(19X,60('-'))
103   FORMAT(19X,5(' ',2X,F6.2,' % '))
104   FORMAT(' PROPOSAL',I3,' * NPV *',5(F11.2,1X))
105   FORMAT(13X,'* B/C *',5(F11.2,1X))
106   FORMAT(I3,F6.2,F11.2)
C
      RETURN
      END
$ENTRY
```